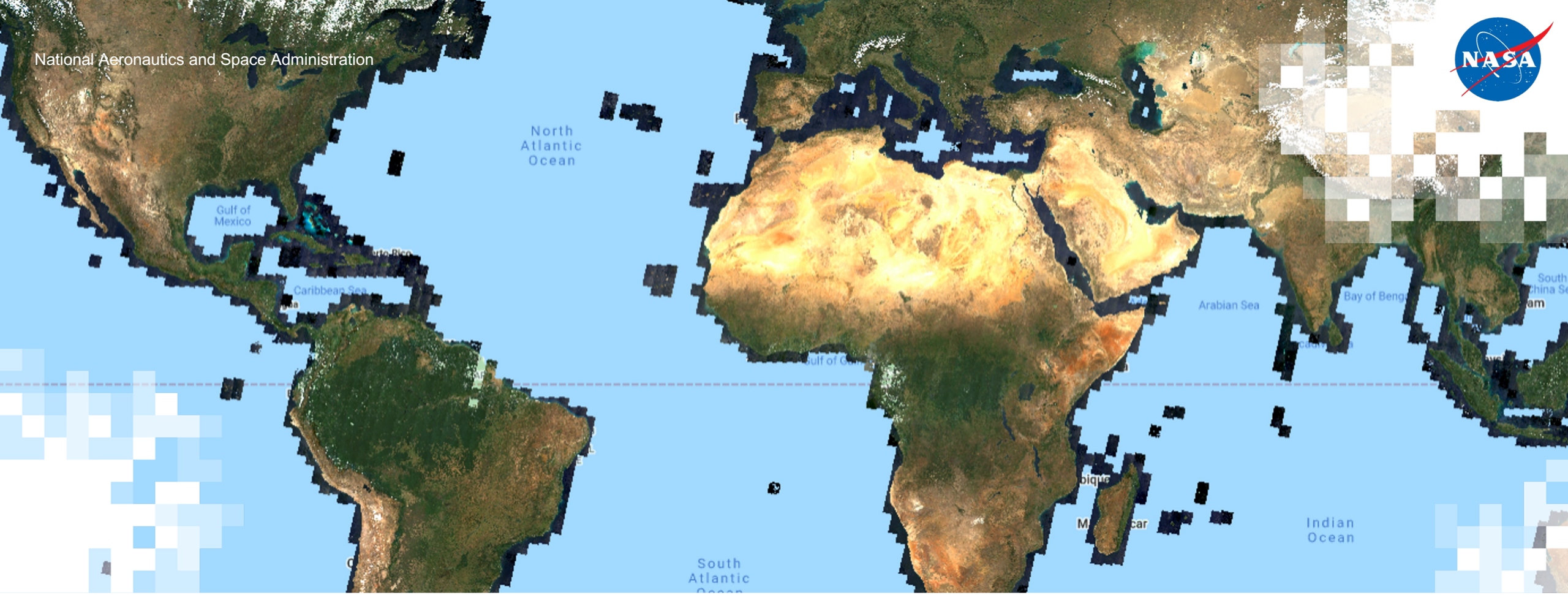


Overview of Land Cover Remote Sensing

Turning Data Into Information

Spectral vs. Informational Classes

Spectral Classes

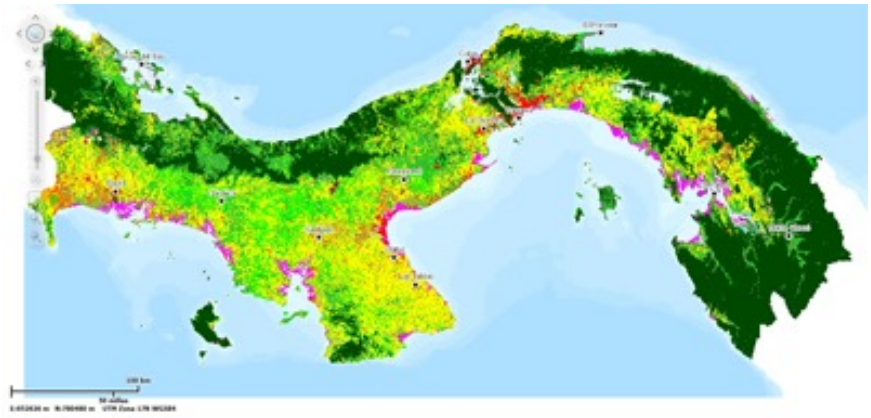
- Groups of pixels that are uniform with respect to their pixel values in several spectral bands

Informational Classes

- Categories of interest to users of the data (i.e., water, forest, urban, agriculture, etc.)

Image classification is the process of grouping spectral classes and assigning them informational class names.

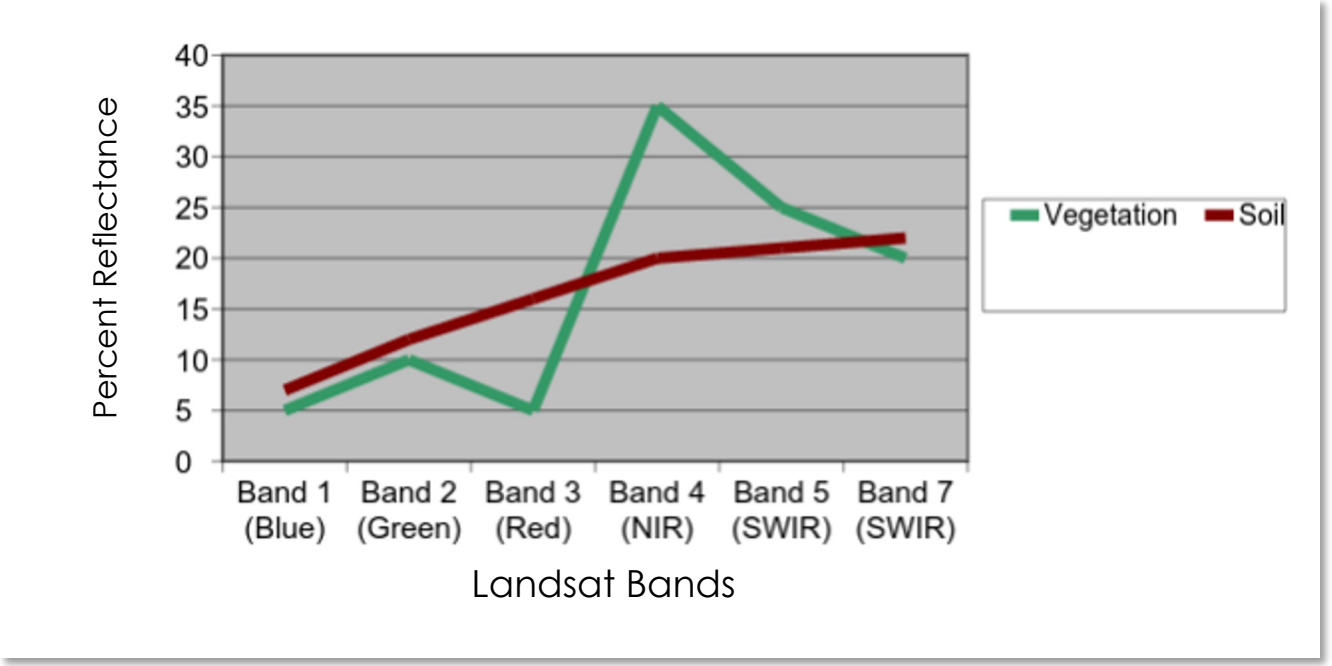
Satellite image of Panama



Land cover map of Panama

Land Cover Mapping Basics

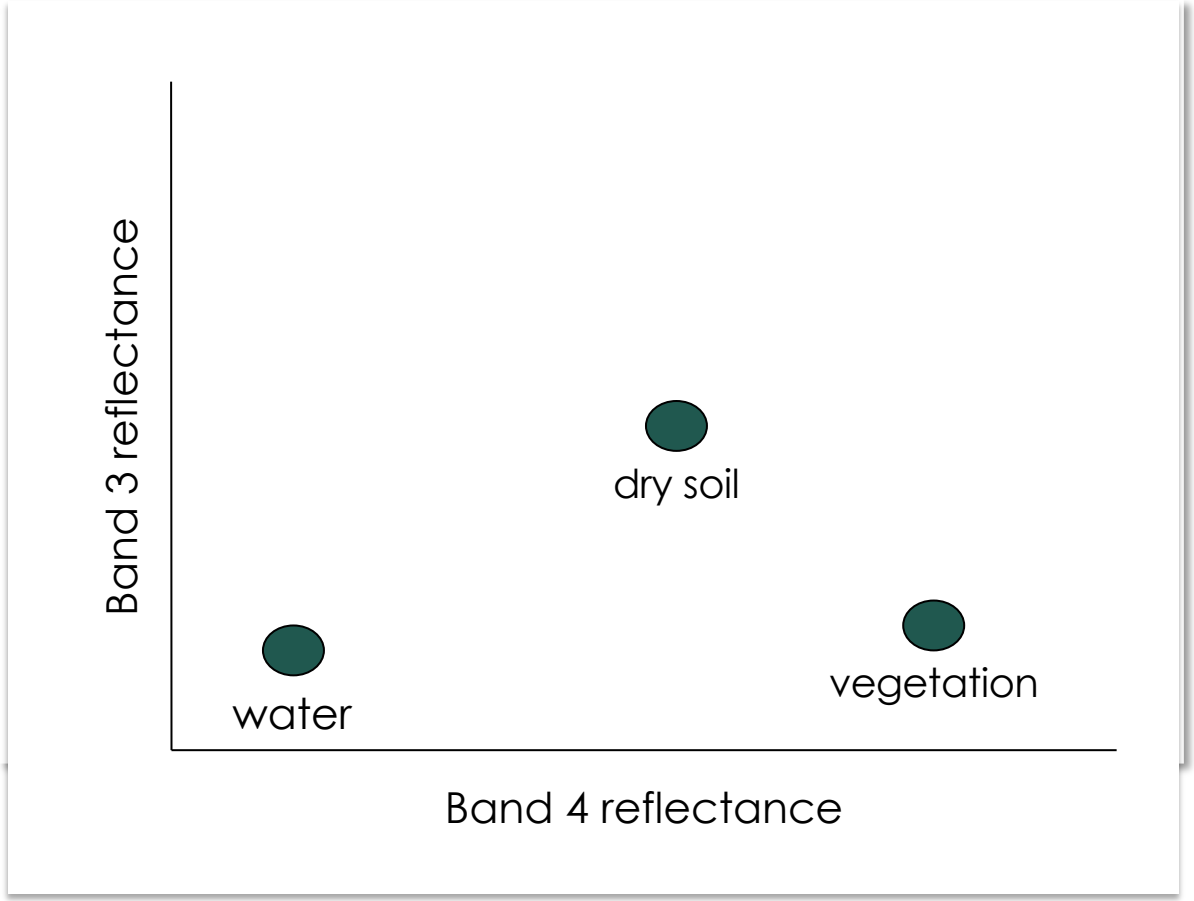
- Objects on the ground reflect electromagnetic radiation differently in different wavelengths.
- That is called the object's **spectral signature.**
- Example: Green vegetation absorbs Red wavelengths but reflects NIR wavelengths



Land Cover Mapping Basics

Spectral Plots

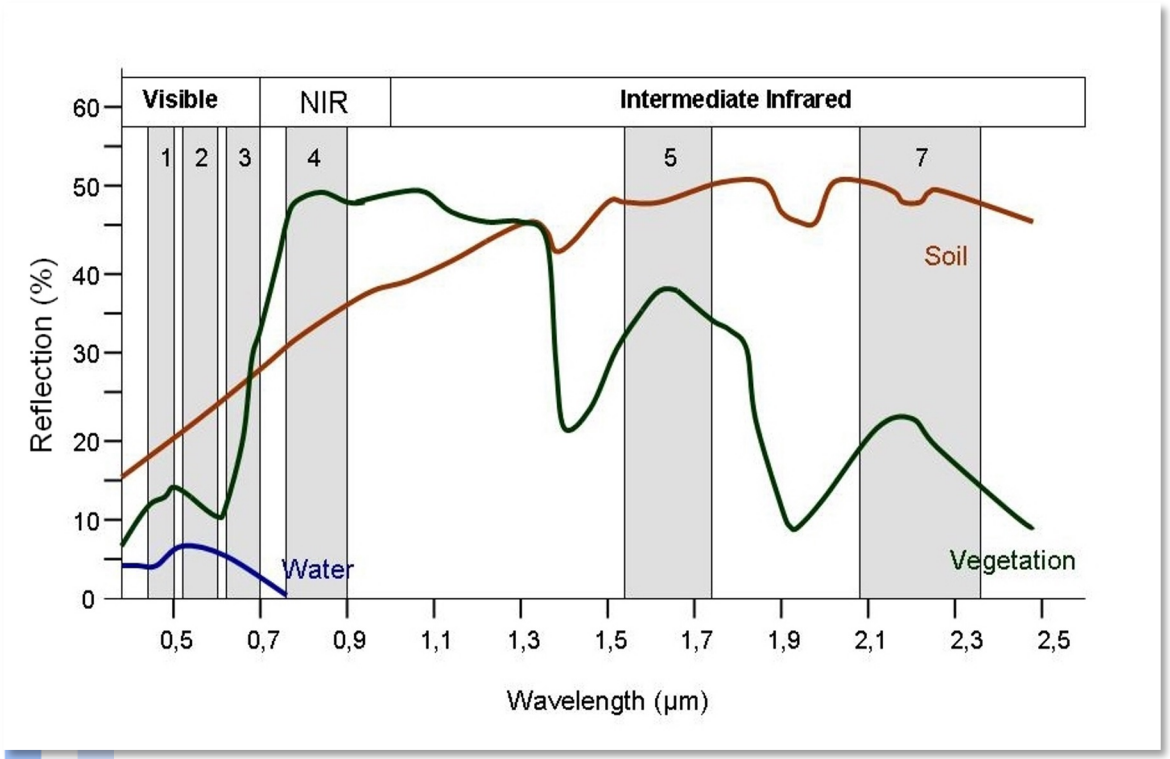
- Look at spectral signatures by plotting Band 3 (Red) vs. Band 4 (NIR) reflectance values.
- Objects (soil, water, and vegetation) fall in different places in the plot.
- The software uses this to distinguish between different land cover types.



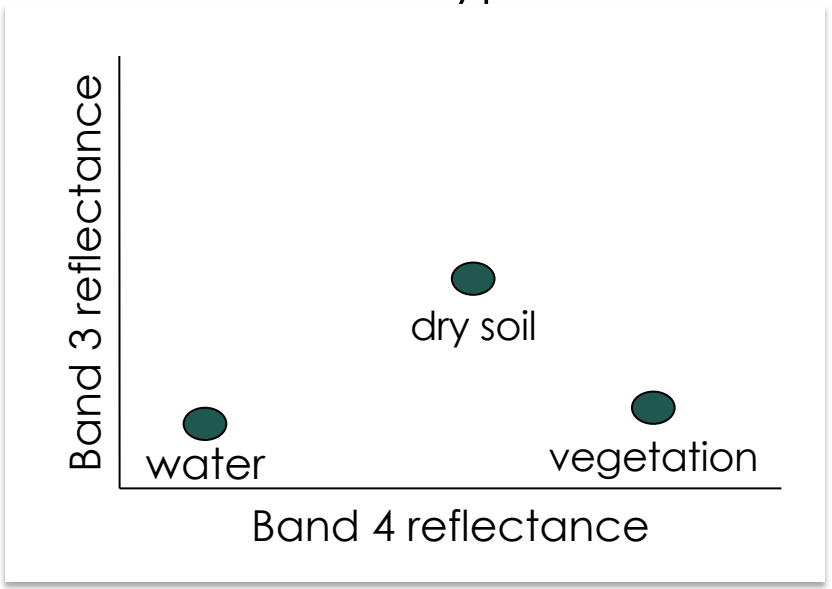
Land Cover Mapping Basics

Spectral Plots

- Now we will look at spectral signatures a little differently by plotting Band 3 (Red) vs. Band 4 (NIR) reflectance values.

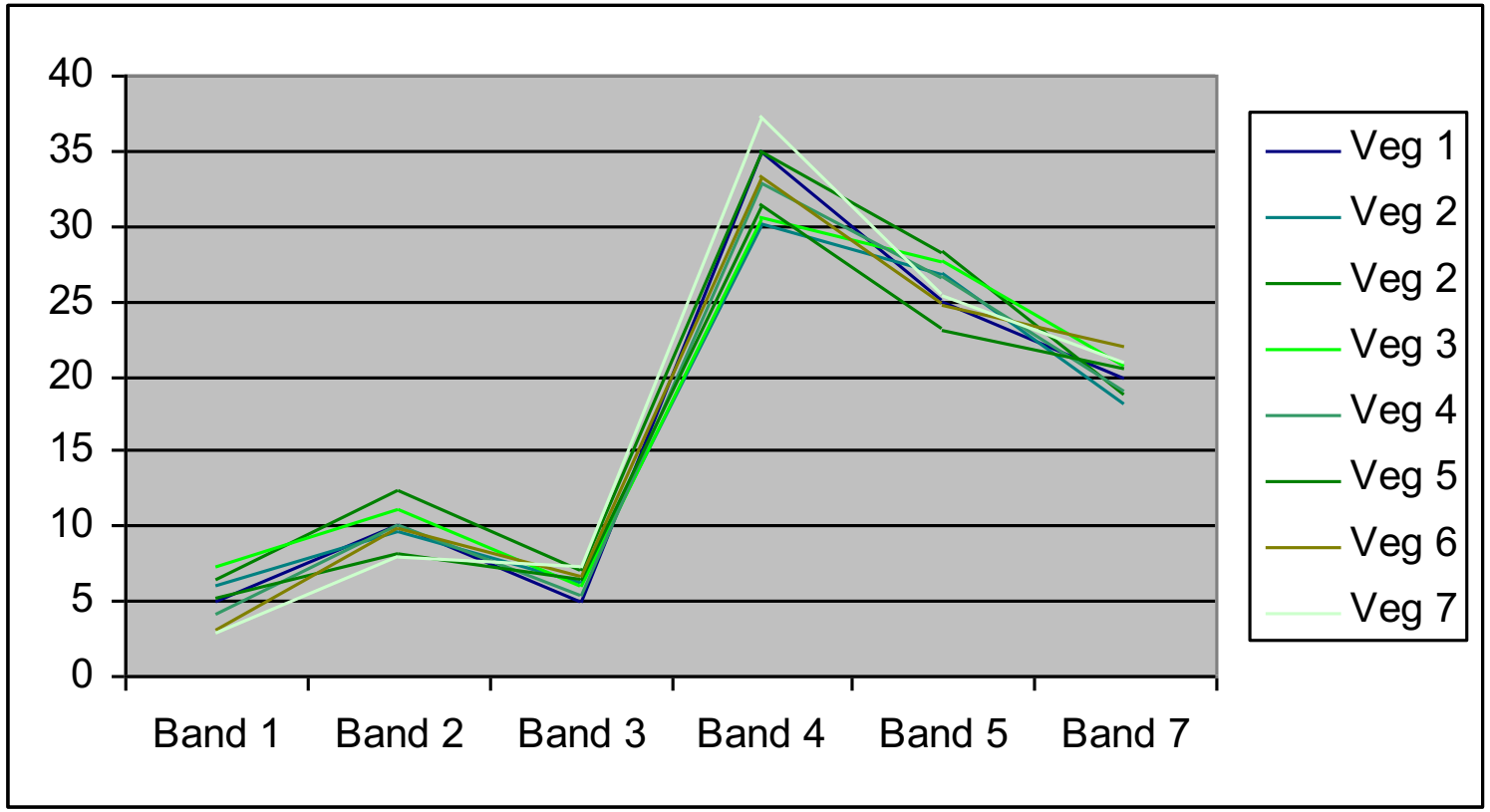


- When you do this, you see the objects (soil, water, and vegetation) fall in different places in the plot.
- The software (QGIS and others) uses this information to distinguish between different land cover types.



Spectral Signatures

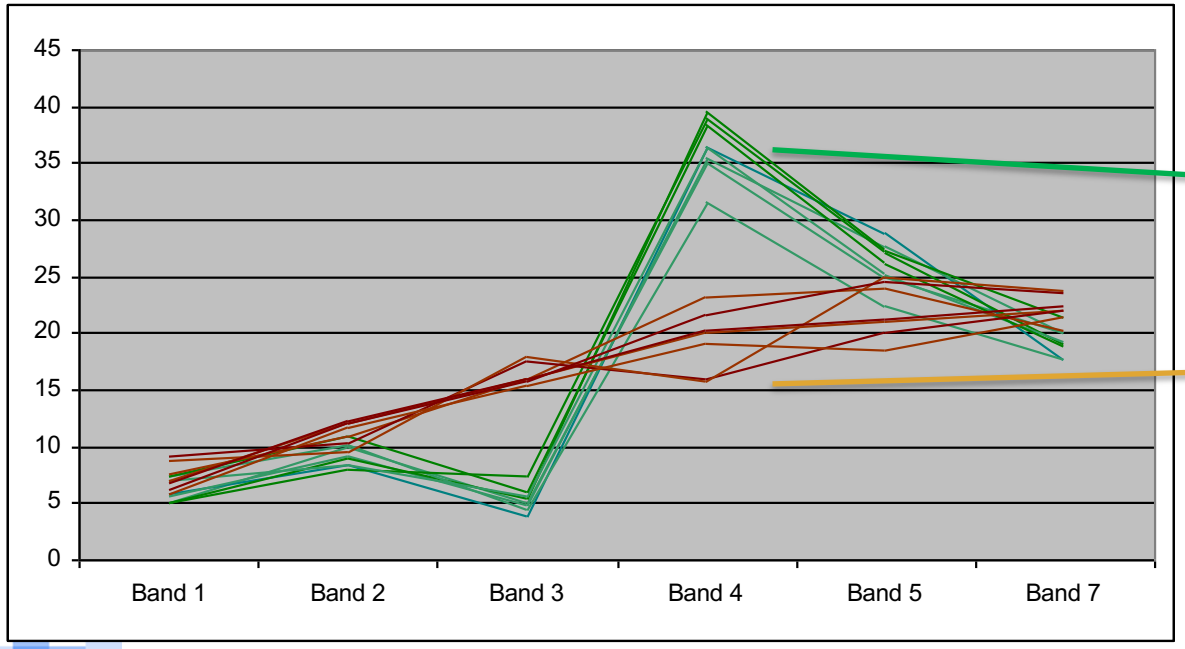
- There is some variation in reflectance values at different wavelengths.
- Depending on the land cover classes you want, the trick is to identify this variability.

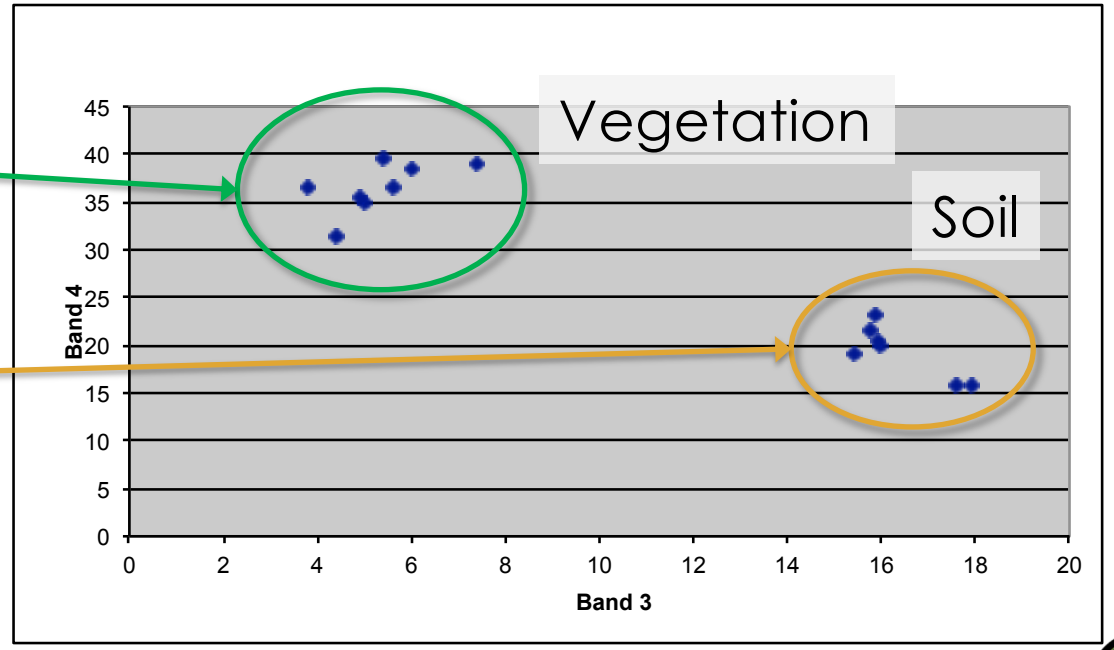


Spectral Variation

- Easier: distinguishing between broad classes
  - e.g., vegetation and soil
- Harder: distinguishing *within* broad classes

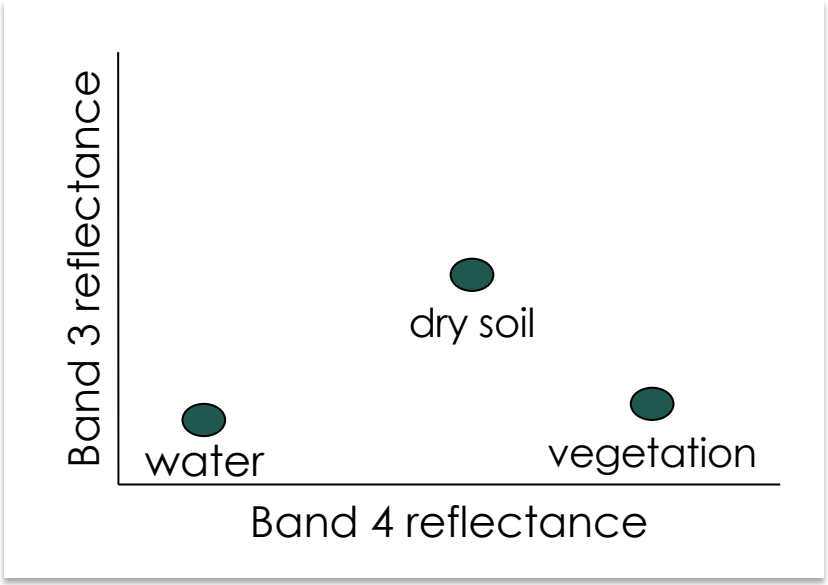
- Variation within and between type (broad classes) is below.



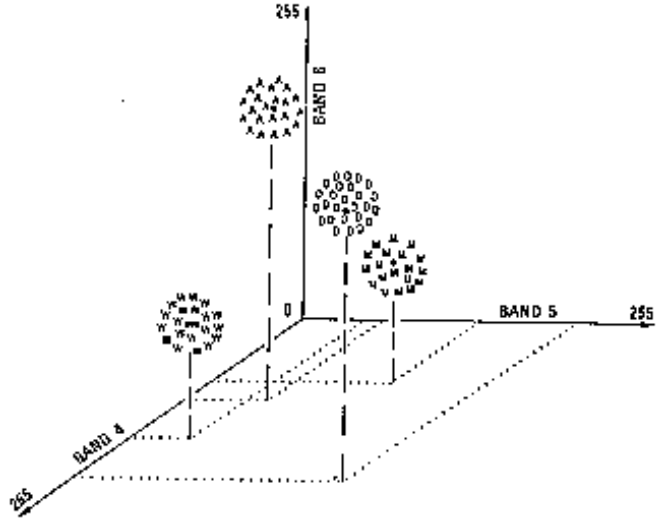


Multi-Dimensional Spectral Plots

- When looking at spectral plots, each band represents a different dimension.
- For example, this is a 2-dimensional plot:



- In a spectral plot, pixels are plotted in n-dimensional space (where n represents the number of bands).
- This is an example of a 3-dimensional spectral plot:



Sabins, F. F. (1987). *Remote Sensing: Principles and Interpretation* (2nd ed.). W.H. Freeman and Company.

Image Classification

- Requires delineating boundaries of classes in n-dimensional space using class statistics
- Each group of pixels is characterized by:
  - min.
  - max.
  - mean
  - standard deviation
- All the pixels in the image that fall within those statistics are given those labels.

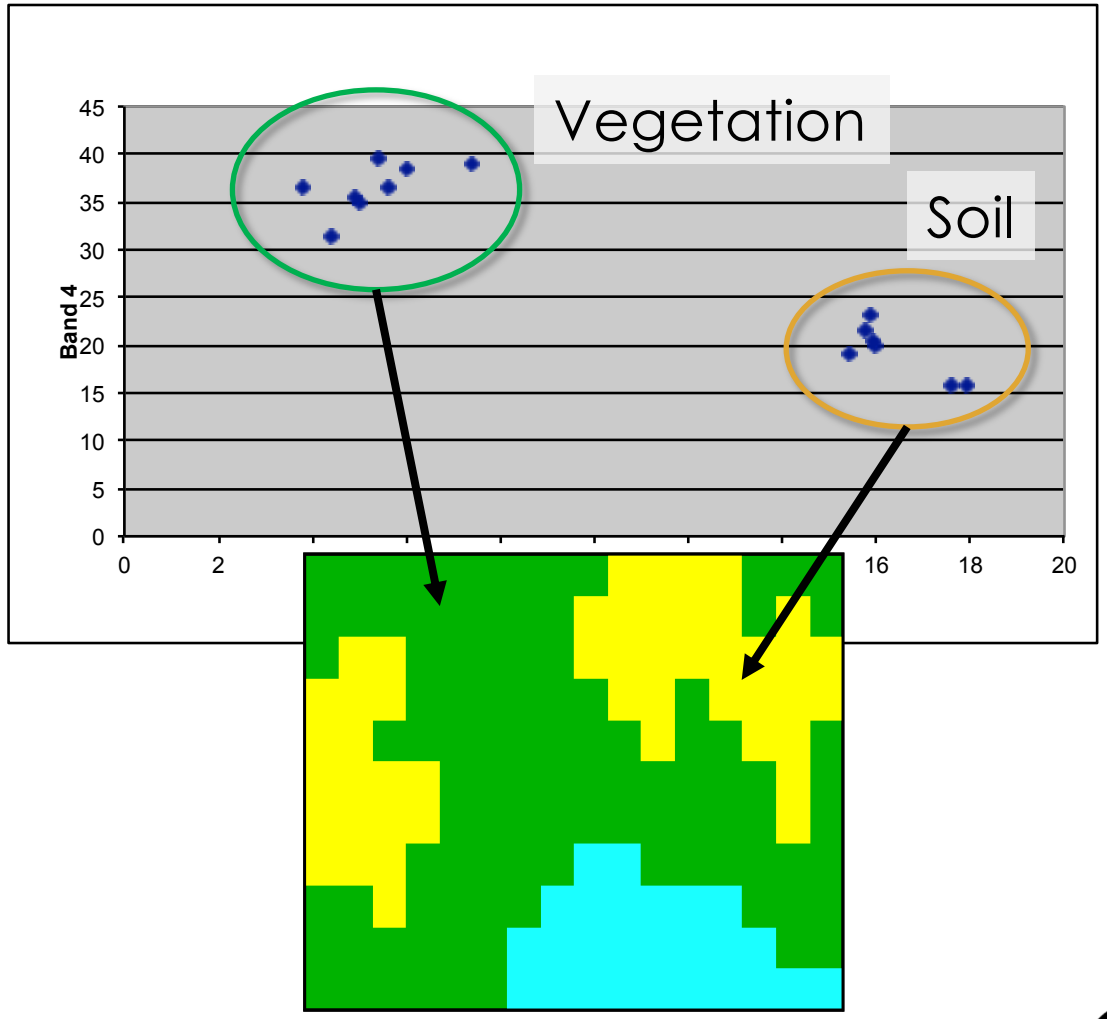
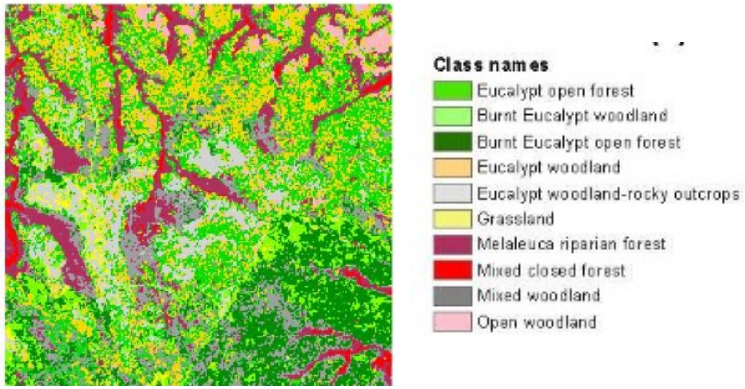


Image Classification (Approaches)

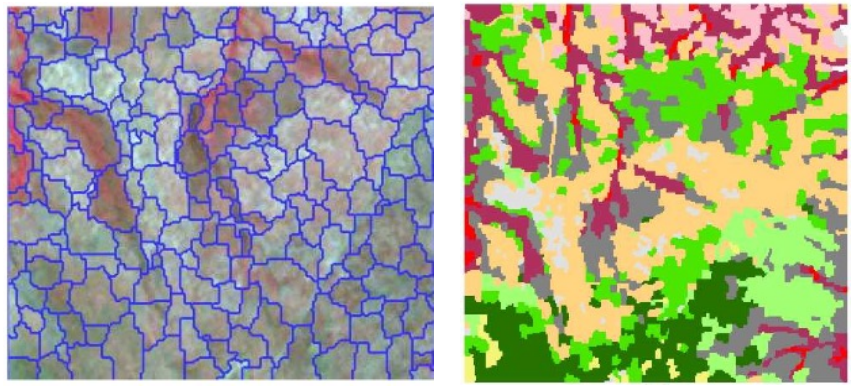
Pixel-Based

- Each pixel is grouped in a class
- Useful for multiple changes in land use within a short period of time
- Best for complete data coverage and a need for methods to ensure time series consistency at the pixel level



Object-Based

- Pixels with common spectral characteristics are first grouped together (segmentation)
- Useful for:
  - Reducing speckle noise in radar images
  - High resolution imagery

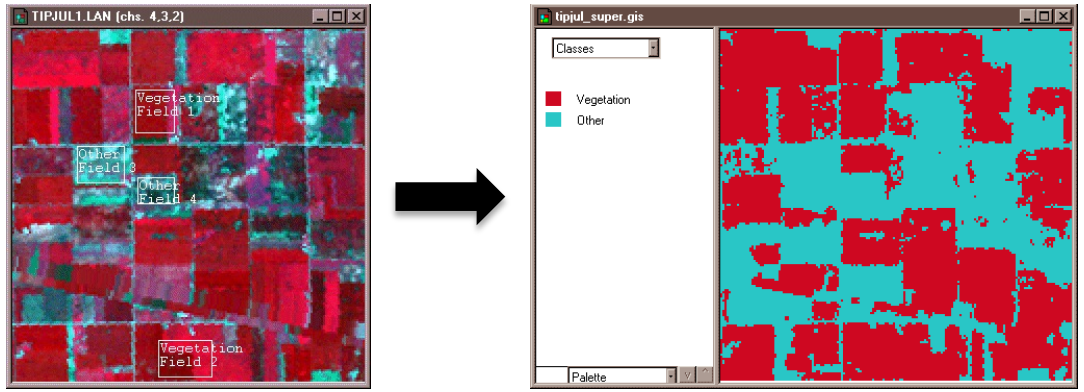


Whiteside, T., & Ahmad, W. (2005, September). A comparison of object-oriented and pixel-based classification methods for mapping land cover in northern Australia. *Proceedings of SSC2005 Spatial intelligence, innovation and praxis: The national biennial Conference of the Spatial Sciences Institute*.

Image Classification (Methods)

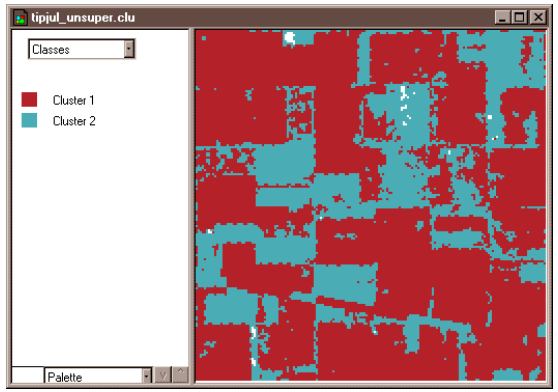
Supervised

- Uses expert-defined areas of known vegetation types (training areas) to tune parameters of classification algorithms
- Algorithm then automatically identifies and labels areas similar to the training data



Unsupervised

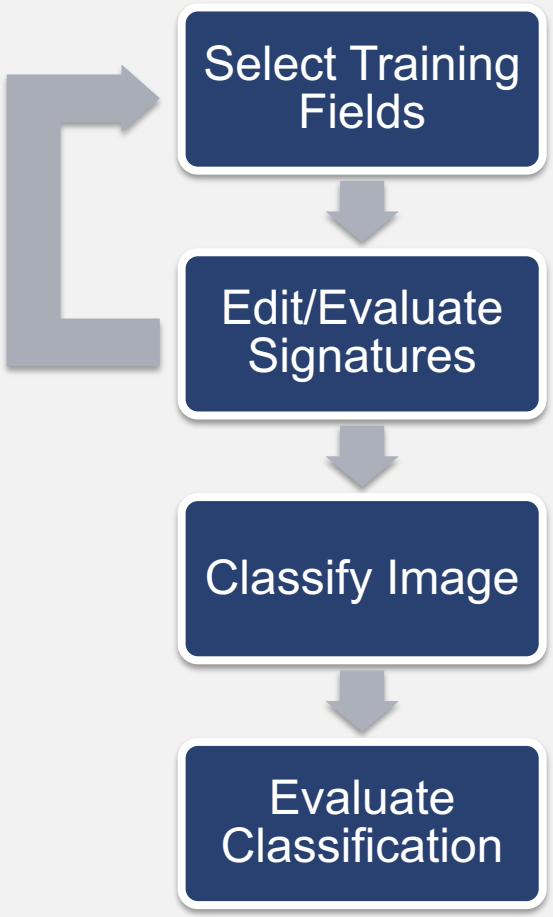
- Uses classification algorithms to assign pixels into one of a number of user-specified class groupings
- Interpreters assign each of the groupings of pixels a value corresponding to a land cover class



Credit: David DiBiase, Penn State Department of Geography

Supervised vs. Unsupervised Classification

Supervised



Unsupervised

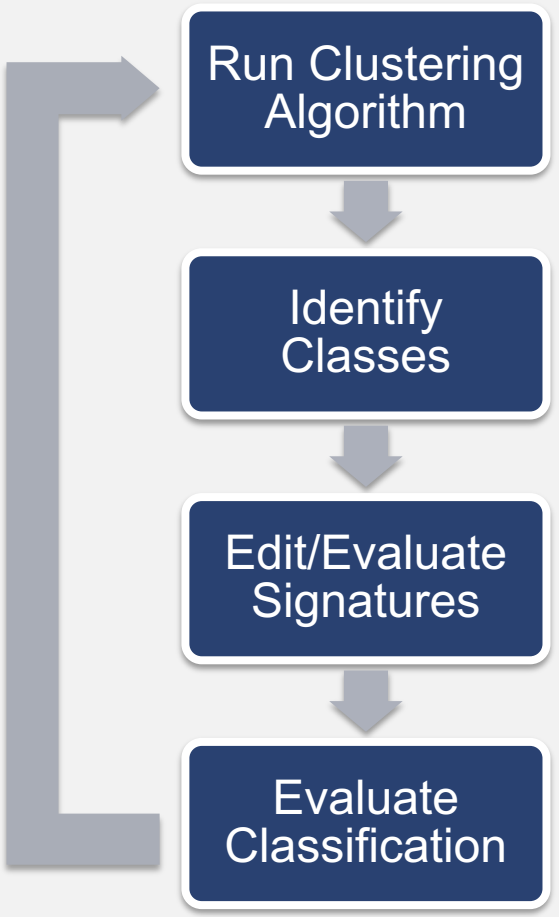
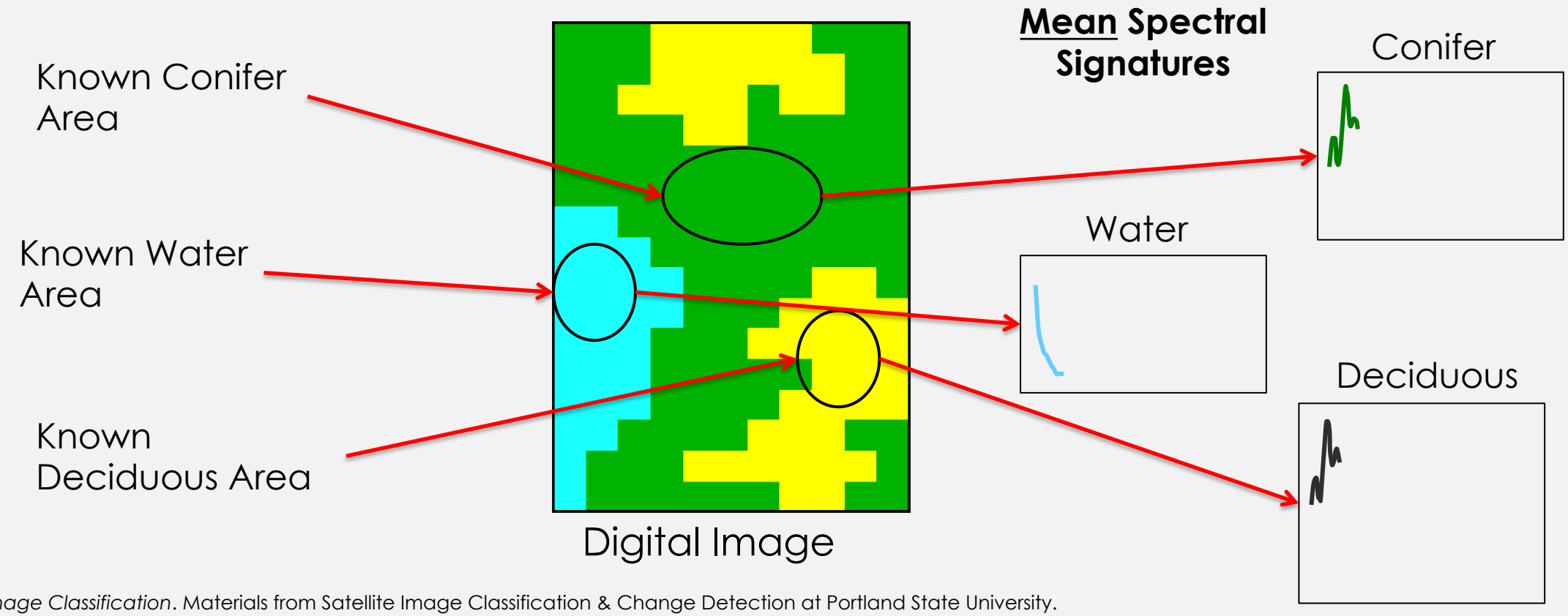


Image Classification (Supervised Method)

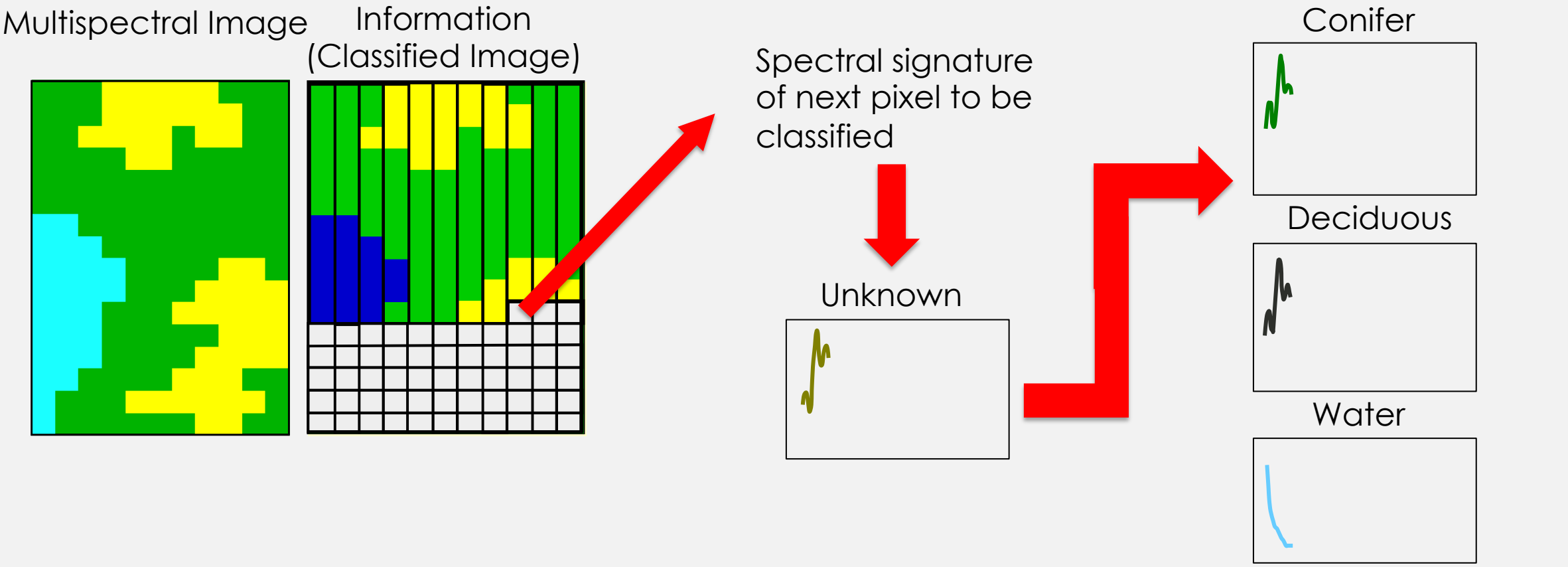
Supervised classification requires the analyst to select training areas where they know what is on the ground, and then digitizes a polygon within that area.



Sutton, L. *Image Classification*. Materials from Satellite Image Classification & Change Detection at Portland State University.

Image Classification (Supervised Method)

The spectral signature of each pixel gets matched with the training signatures and the image is classified accordingly.



Training Sites (or Regions of Interest [ROI])

Key Characteristics

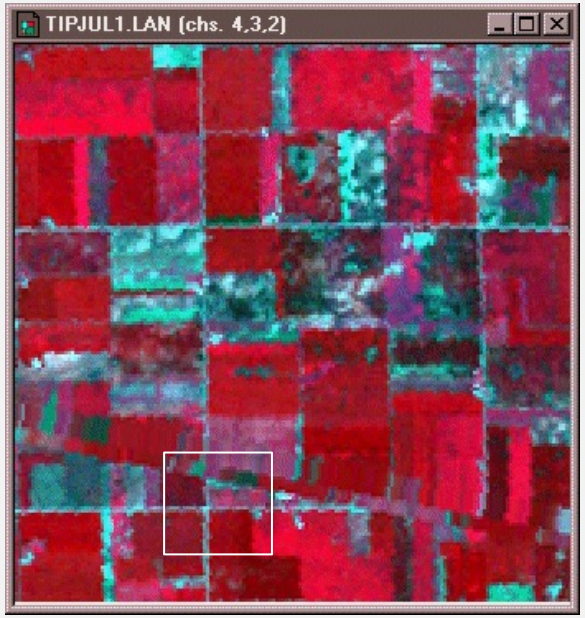
- **General rule:** If using n bands of data, then >10n pixels of training data should be collected for each class.
- **Size:** Must be large enough to provide accurate estimates of the properties of each class.
- **Location:** Each class should be represented by several training areas positioned throughout the image.
- **Number:** 5 to 10 per class minimum. You want to make sure spectral properties of each class are represented.
- **Uniformity:** Each training area should exhibit unimodal frequency distribution for each spectral band.

Selecting training sites

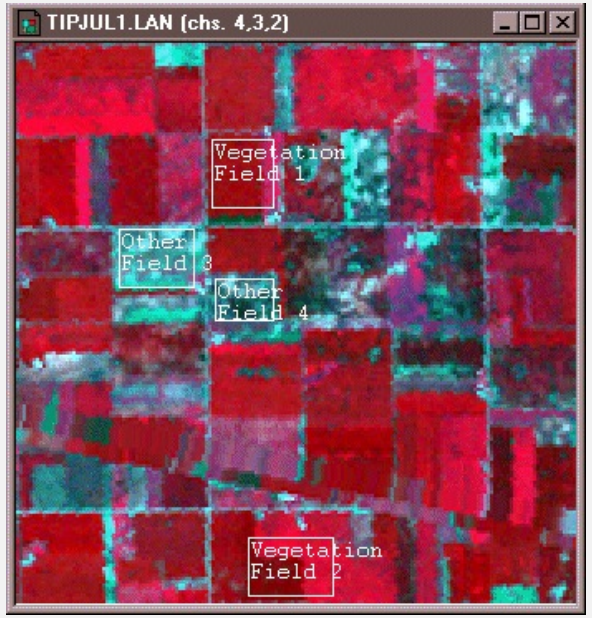
Minimizing confusion

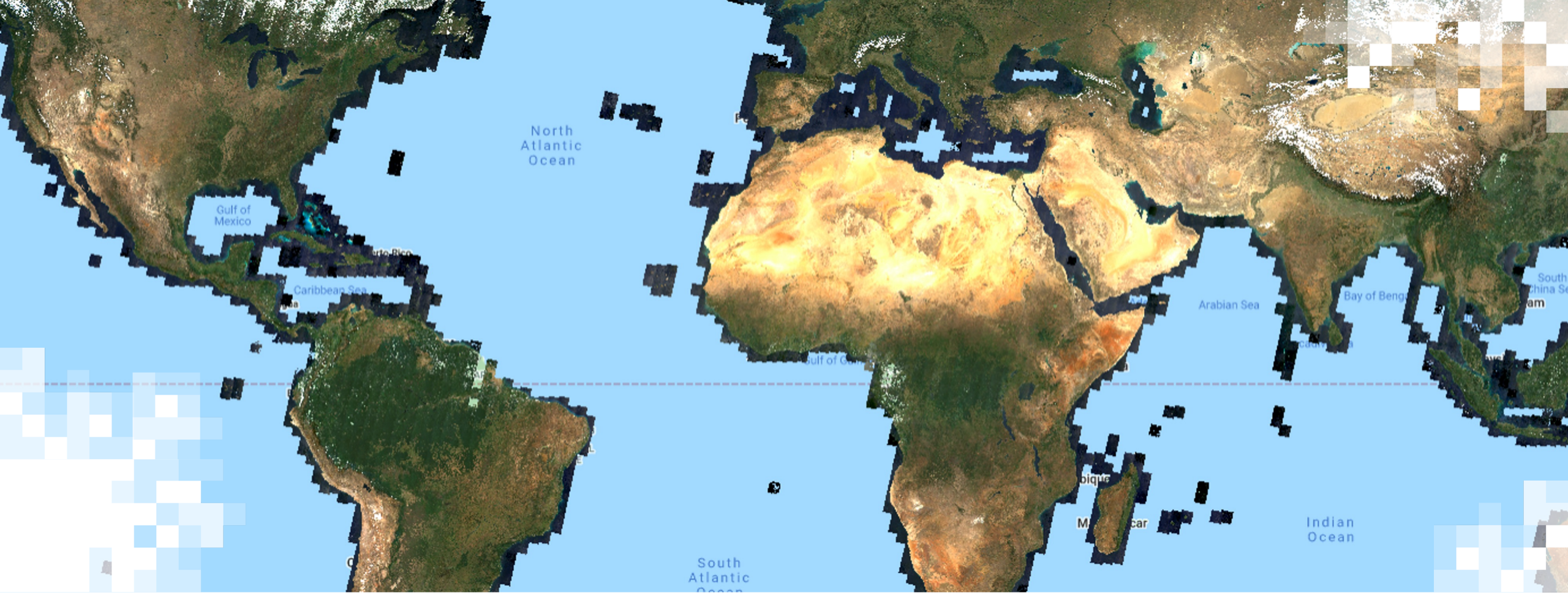
- Confusion of land cover classes is common in land cover classification because:
  - Land cover types are spectrally similar (i.e., different vegetation or crop types)
  - Shadows or clouds
  - Training sites are delineated too broadly OR they are not capturing enough variability.

This training site includes too many land cover types and therefore too much spectral variability.



These training sites better represent the spectral variability in agricultural fields.

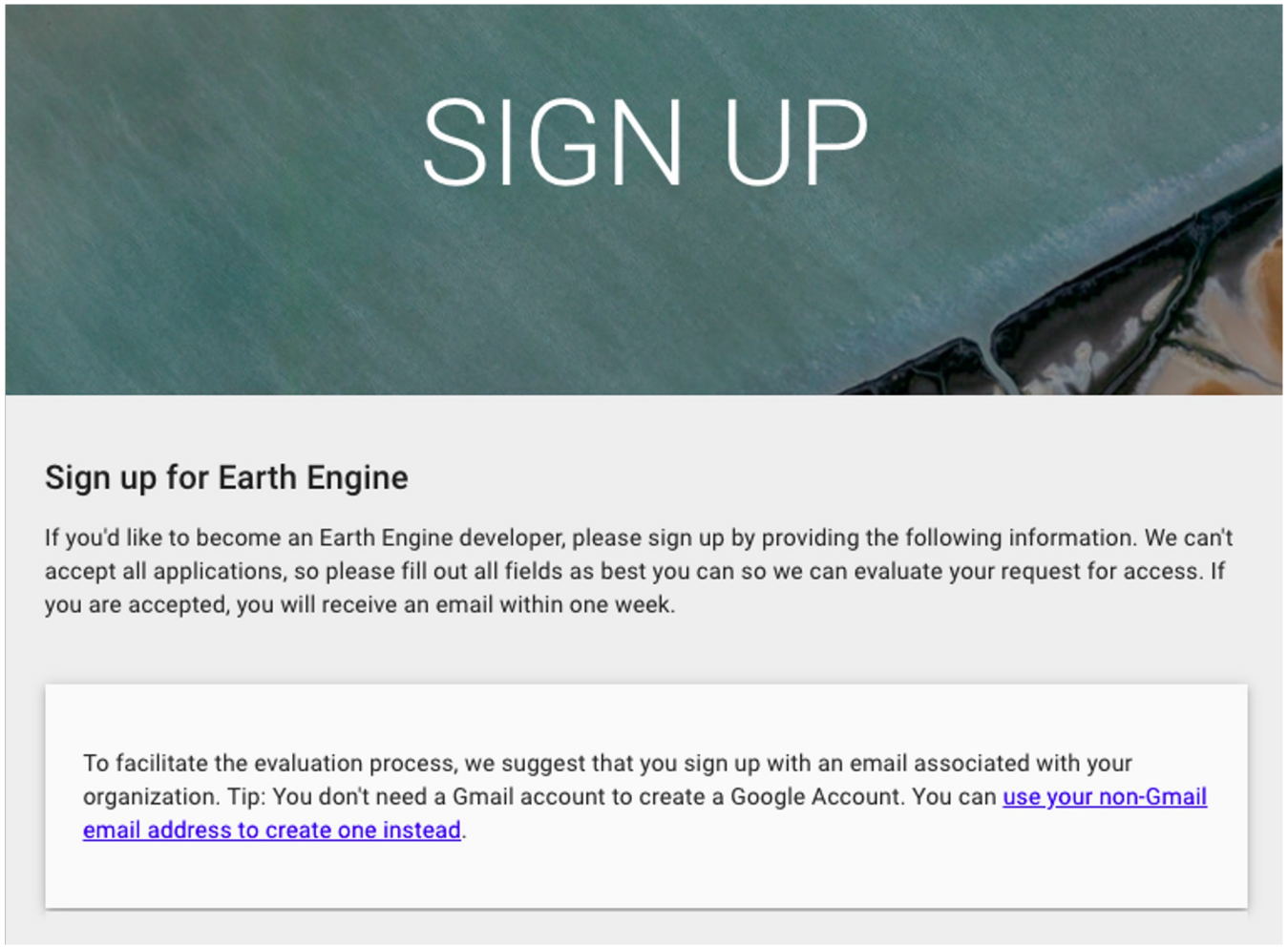




Introduction to Google Earth Engine Functionalities and Available Data Types

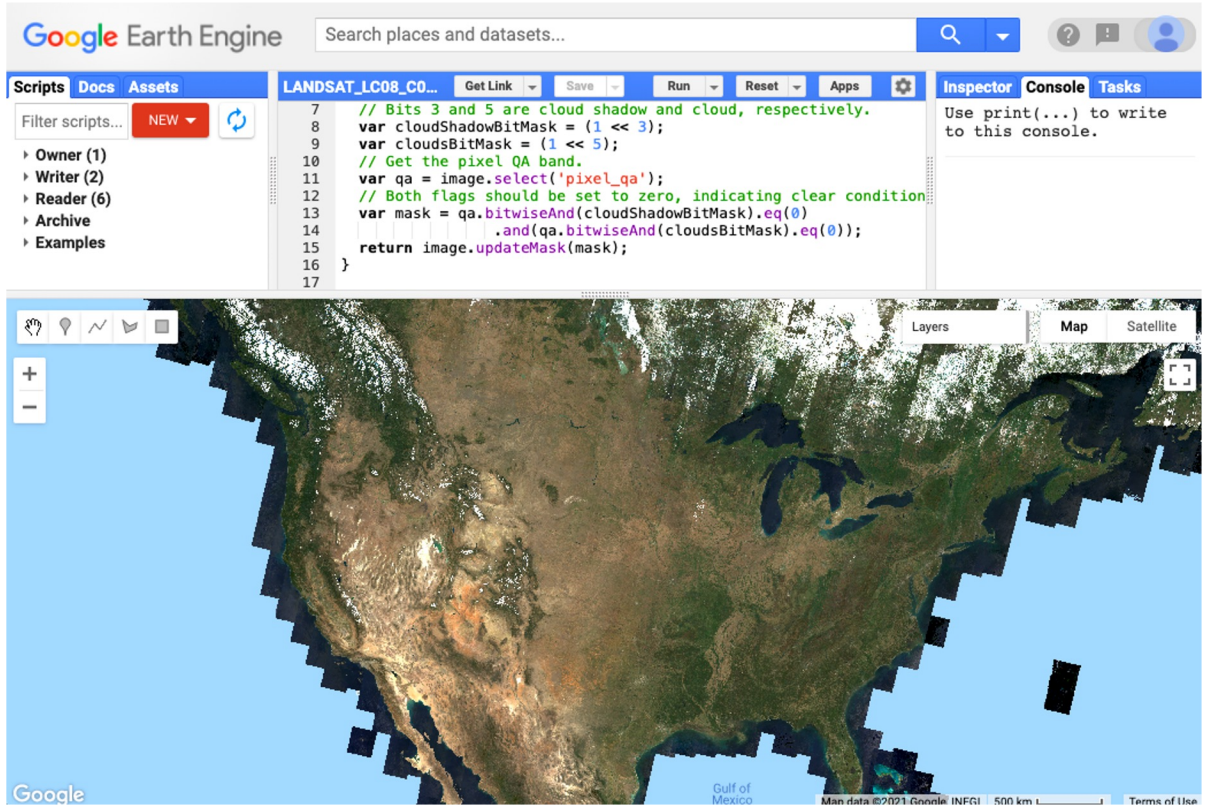
Google Earth Engine Account Reminder

- Make sure you sign up for a Google Earth Engine account as soon as possible, if you haven't already, using the link below:
  - https://signup.earthengine.google.com/#!/
  - A Gmail address is not required. It is recommended that you use your work/institutional email.



Cloud-Based Raster Computing for Remote Sensing Analysis

- Cloud-based raster computing removes barriers and limitations related to…
  - Data hosting and storage
  - Imagery access and availability
  - Personal computing capabilities
- GEE is also free for scientists, researchers, and developers.



Google Earth Engine code editor interface using the JavaScript API, displaying Landsat 8 surface reflectance true color imagery for the U.S. Credit: Google Earth Engine Developers

The Google Earth Engine Platform

- Google Earth Engine (GEE) takes advantage of cloud computing capabilities to provide users with a single place for **accessing satellite data, applying remote sensing methodologies, and displaying analysis results**.
- GEE's application programming interface (API) allows users to easily apply land cover monitoring algorithms and classifications with coded commands.

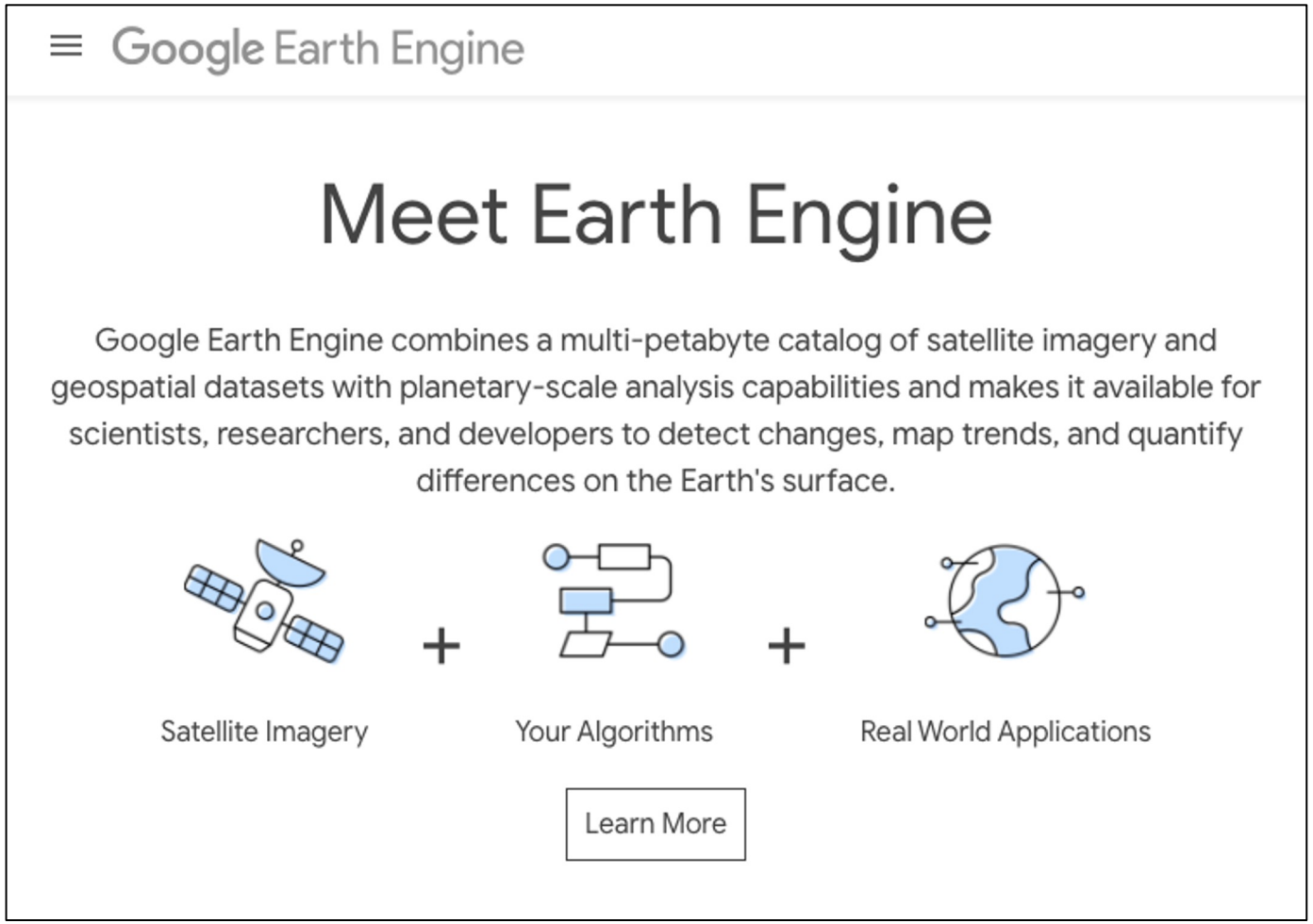
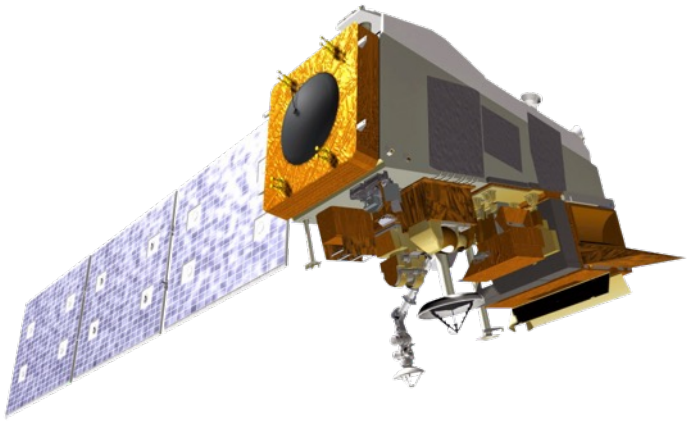
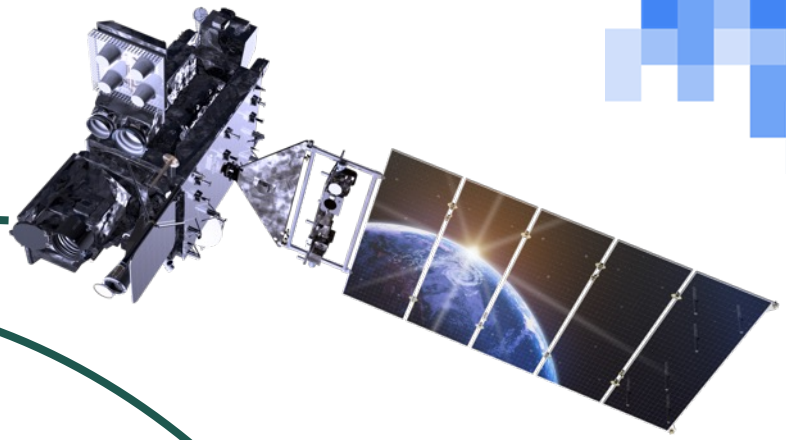
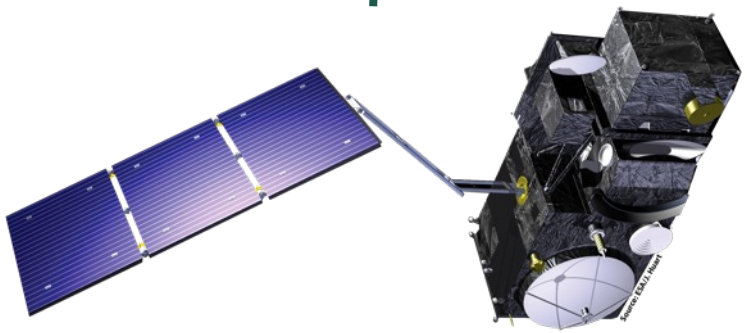
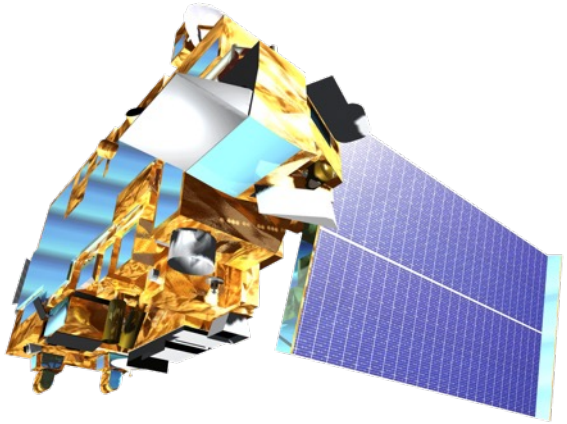


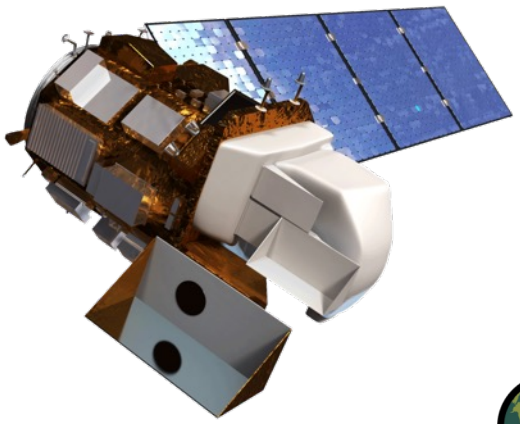
Image Credit: Google Earth Engine







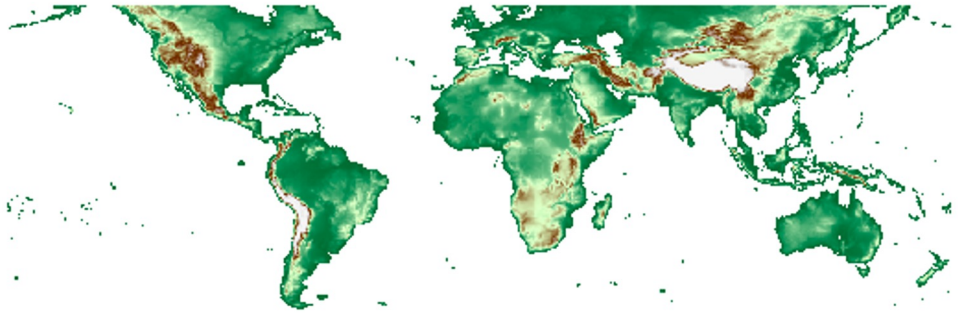




Application Programming Interface (API)

- The Earth Engine JavaScript API is currently the most widely used method of working with GEE.
- A Python API through Google Colaboratory (Colab) is also available for those interested in using Python.
  - This is a bit more complicated than working directly in the GEE code editor with JavaScript.

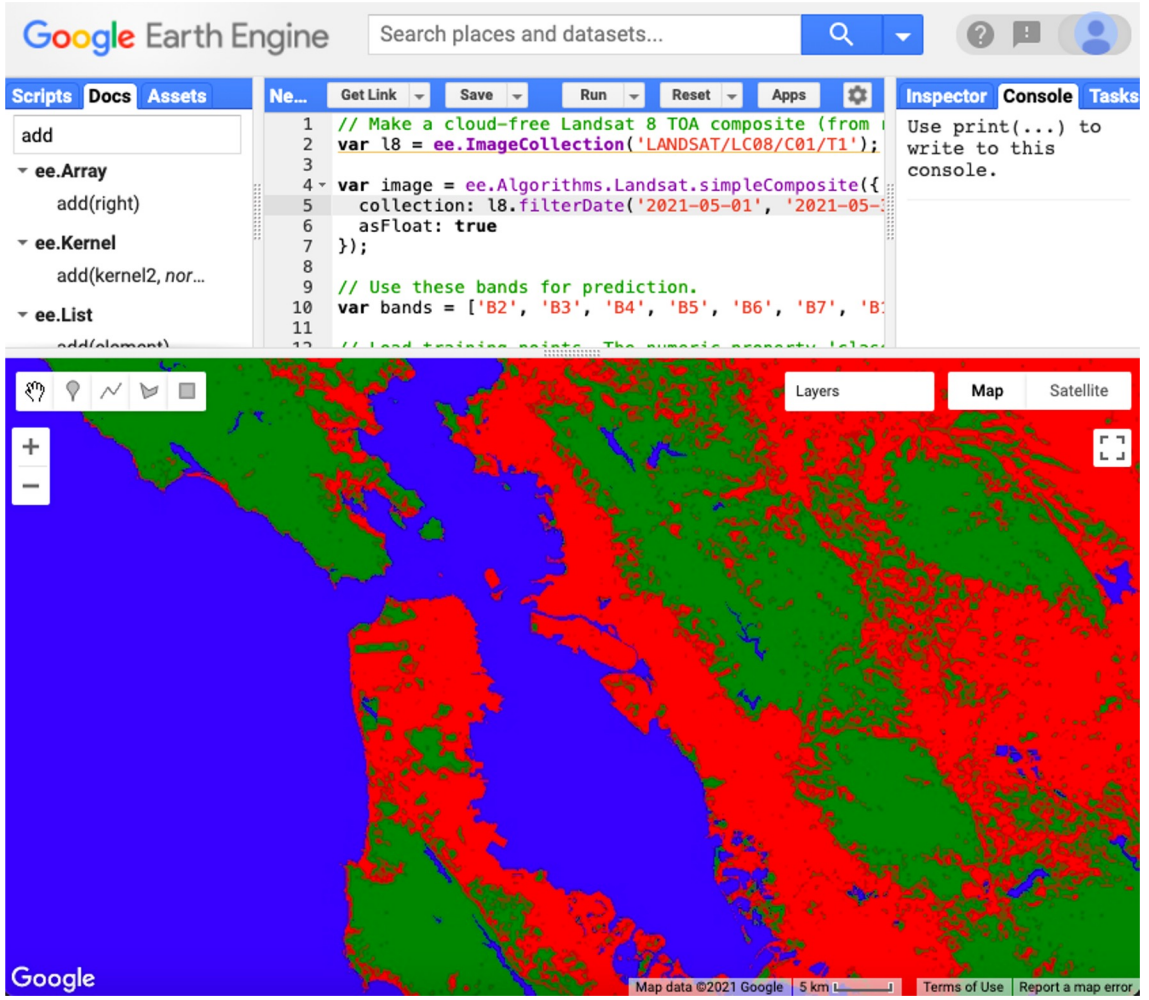
```
# Import the Image function from the IPython.display module.
from IPython.display import Image

# Display a thumbnail of global elevation.
Image(url = dem.updateMask(dem.gt(0))
  .getThumbURL({'min': 0, 'max': 4000, 'dimensions': 512,
                'palette': ['006633', 'E5FFCC', '662A00', 'D8D8D8', 'F5F5F5']}))
```



Google Colab notebook using a coded section to display elevation in an output cell. Credit: Google Colab

Google Earth Engine Functionality

- Uses of GEE for satellite imagery analysis include:
  - Automation of data processing and display
  - Near real-time monitoring (limited by the availability of data in the catalog)
  - Machine learning algorithm application
  - Graphical User Interface implementation



Simple Classification and Regression Trees (CART) classifier implemented in the GEE API to identify three classes urban, forest, and water in the San Francisco Bay Area for May 2021 using Landsat 8 imagery. Credit: Google Earth Engine Developers

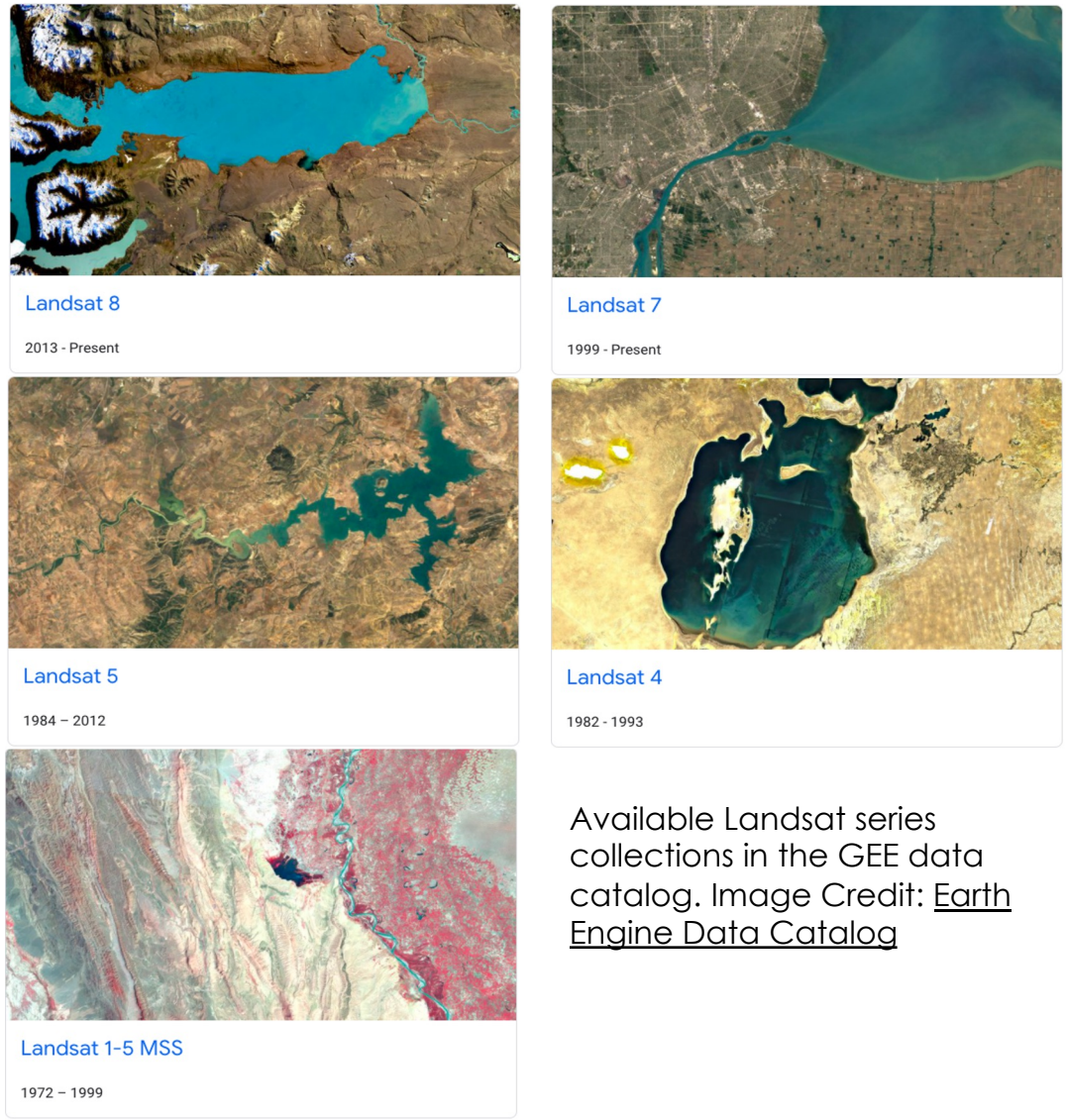
GEE Land Applications

- Long-term monitoring of landscape change and land cover type
- Computation of indices relevant to land management such as normalized difference indices for vegetation, water, snow, soil, and urban areas
- Landscape time series analysis and change detection
- Summary statistics
- Validation and accuracy assessment methods
- Visualization and presentation of results

Time series of MODIS NDVI displayed using Google Earth Engine. Image Credit: Google Earth Engine Developers

Available Satellite Sensor Data in GEE: Landsat Series

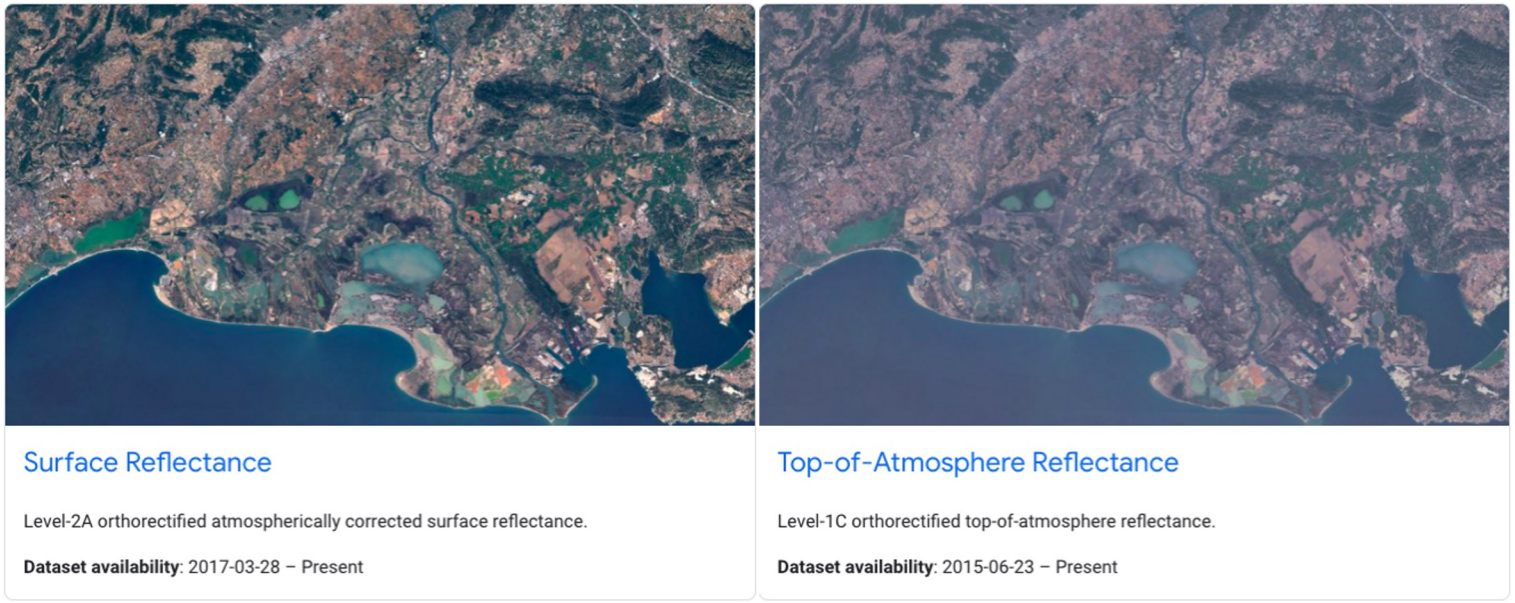
- Data from the entire Landsat series is available for use in GEE, including:
  - **Landsat 1-5**
    - Multispectral Sensor Radiance
  - **Landsat 4-8**
    - Raw Images
    - Top of Atmosphere
    - Surface Reflectance
- The full archive includes data from 1972 to present day, with data from 1982 onward at 30m resolution (Landsat 4-9).
- GEE Data Catalog Link:
  - https://developers.google.com/earth-engine/datasets/catalog/landsat



Available Landsat series collections in the GEE data catalog. Image Credit: Earth Engine Data Catalog

Available Satellite Sensor Data in GEE: Sentinel-2

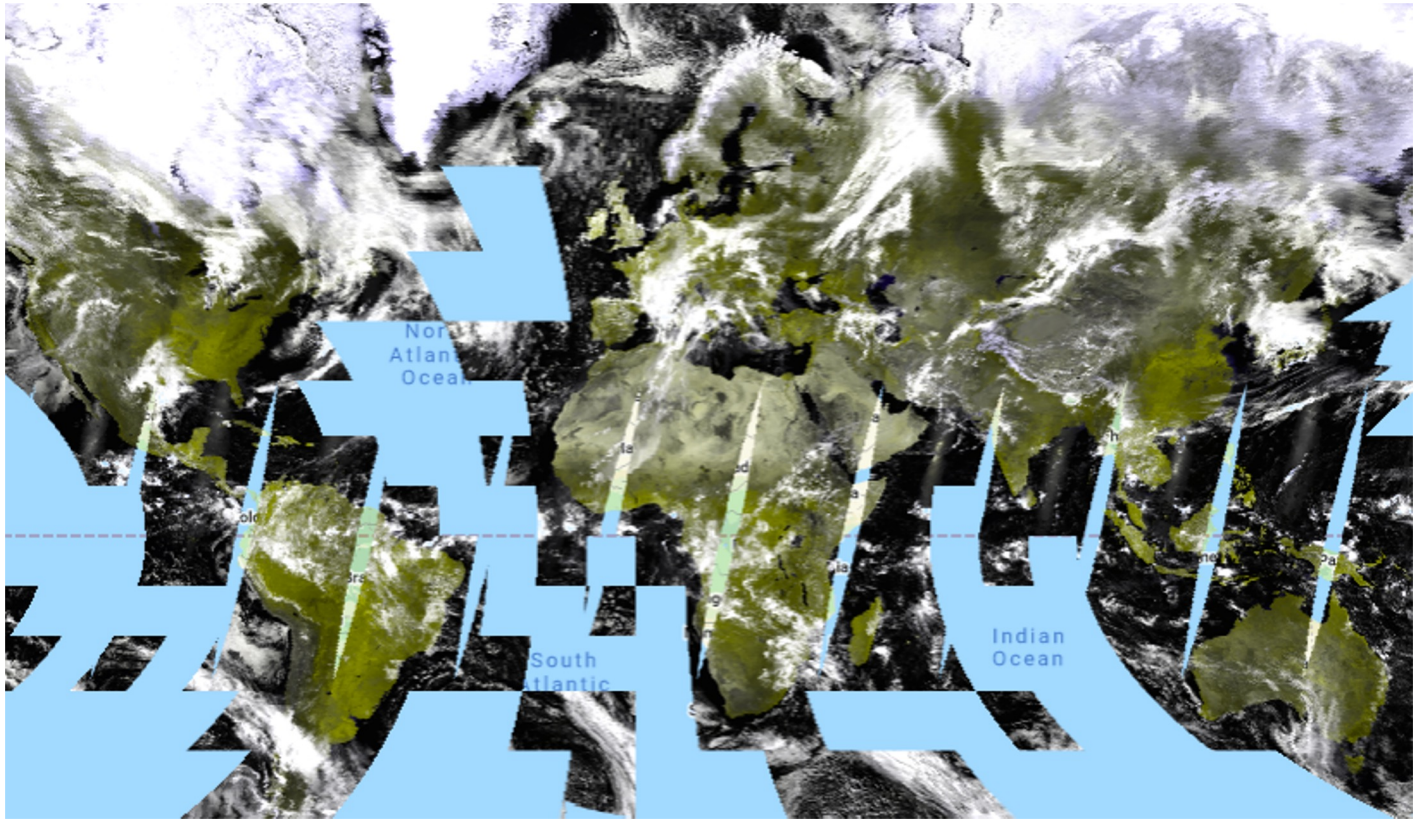
- Available Sentinel-2 data includes:
  - Top of Atmosphere
  - Surface Reflectance
- Sentinel-2 land applications are very similar to those of Landsat, but differences include:
  - 10-20m spatial resolution
  - 5-day revisit
  - Less temporal coverage
- GEE Data Catalog Link:
  - https://developers.google.com/earth-engine/datasets/catalog/sentinel-2



Available Sentinel-2 data products in GEE. Note the temporal coverage starts in 2015 and 2017. Image Credit: Earth Engine Data Catalog

Available Satellite Sensor Data in GEE: MODIS

- MODIS reflectance data products include:
  - Daily, 500m Nadir BRDF-Adjusted Reflectance
  - Daily, Global, 250m Surface Reflectance
  - 8-Day, Global, 250m Surface Reflectance
- Pre-processed products include:
  - Daily, Global, 500m Snow Cover
  - 16-Day, Global, 250m Vegetation Indices
  - Yearly, Global, 500m Land Cover Type

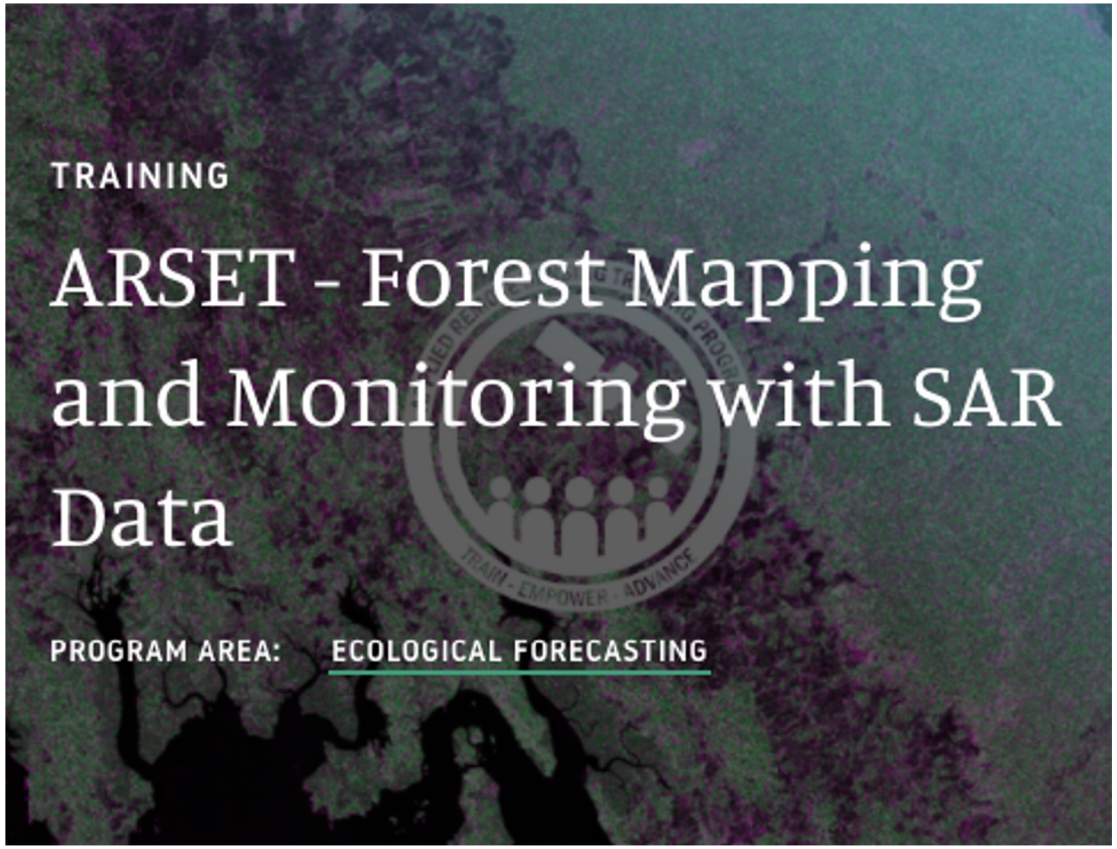


False color image of the Terra Surface Reflectance Daily Global 250m projected in the GEE JavaScript API. Credit: Google Earth Engine Developers

MODIS GEE Catalog Link: https://developers.google.com/earth-engine/datasets/catalog/modis

Available Satellite Sensor Data in GEE: Sentinel-1 SAR

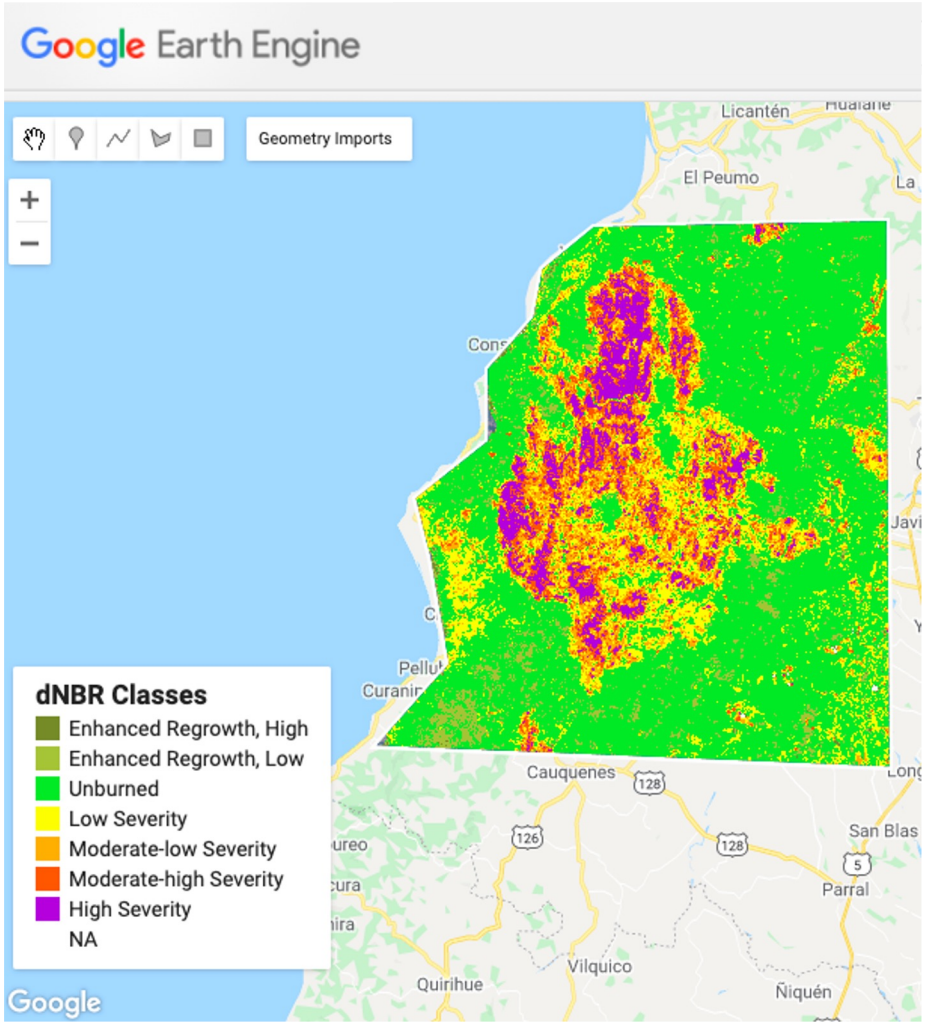
- Pre-processed SAR data from Sentinel-1 is available to work with in GEE.
- Previous ARSET training:
  - Forest Mapping and Monitoring with SAR Data
- GEE Data Catalog:
  - https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S1_GRD



A previous ARSET training details the use of SAR data for land management, particularly in vegetated ecosystems.
Link: ARSET

Applications of GEE for Land Management: Burn Severity

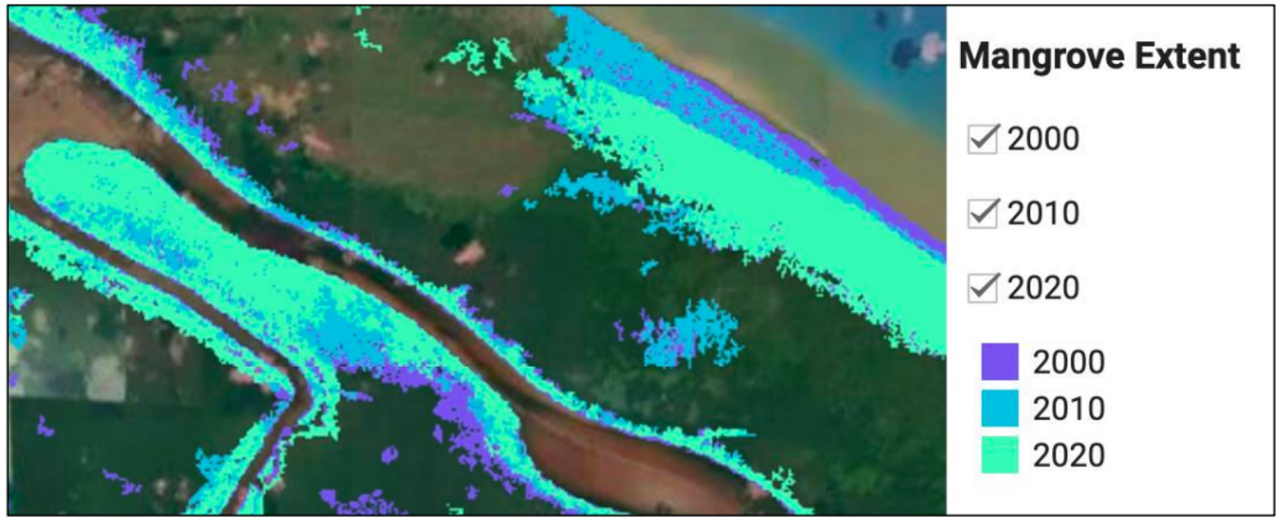
- Burn severity mapping completed in GEE manipulates pre-loaded Sentinel-2 or Landsat 8 data and uses the GEE platform to do quality control and filter data.
- Normalized Burn Ratio (NBR) and differenced NBR (dNBR) are calculated.
- Thresholding rates the severity of wildfire burning to complete a full burn severity assessment.
- Refer to the step-by-step UN-SPIDER burn severity in GEE training



Example of burn severity mapping using Sentinel-2 data in Empedrado, Chile in February 2017. This map was produced using the UN-SPIDER Burn Severity with GEE script. Credit: UN-SPIDER

Applications of GEE for Land Management: Mangrove Mapping

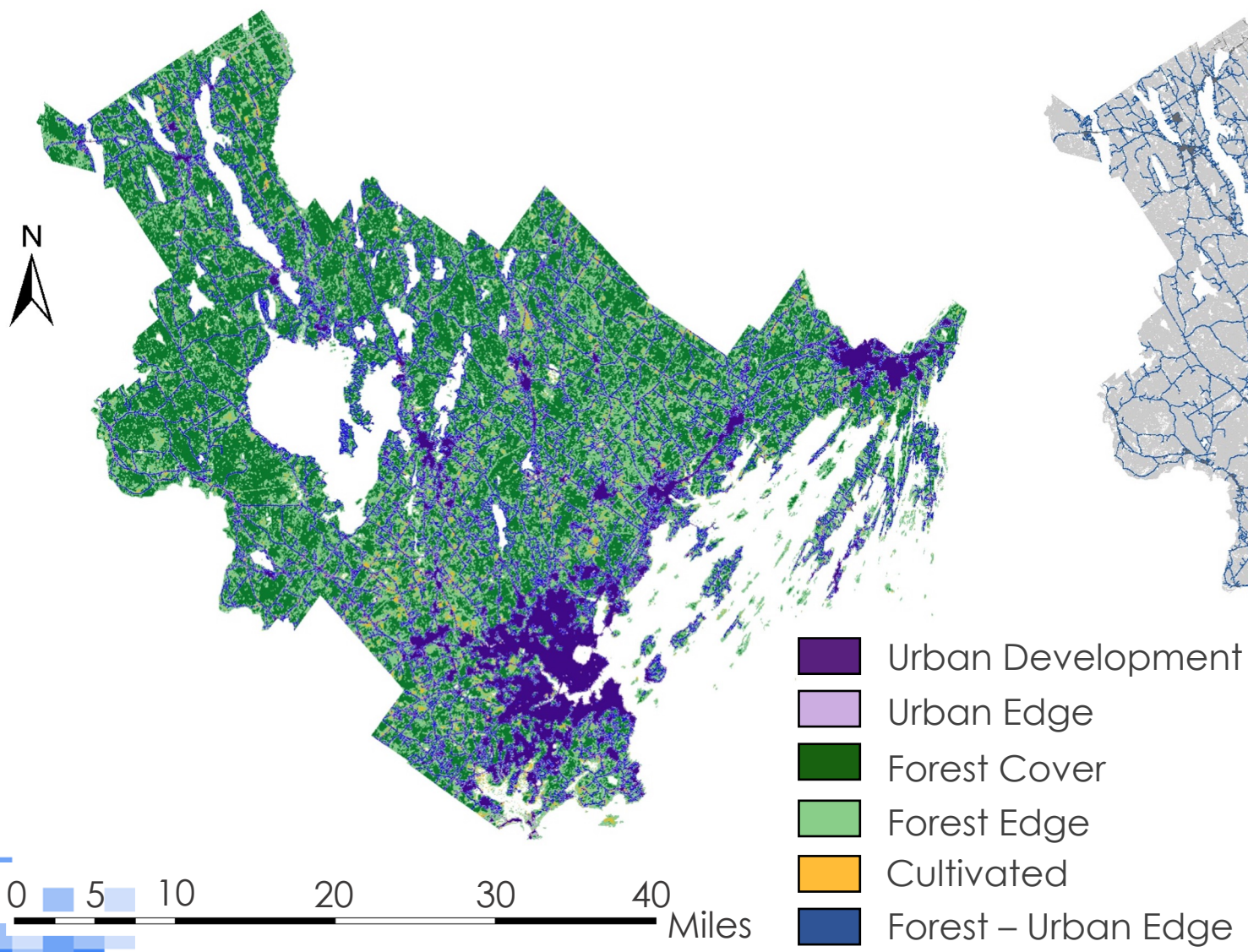
- ARSET training using GEE to map mangroves:
  - Remote Sensing for Mangroves in Support of the UN Sustainable Development Goals
- Random Forest Classification to create a time series for mangrove extent change
- Creation of apps as management and communication tools
- The previously mentioned ARSET SAR training also shows methods of using SAR data in GEE to map mangroves.

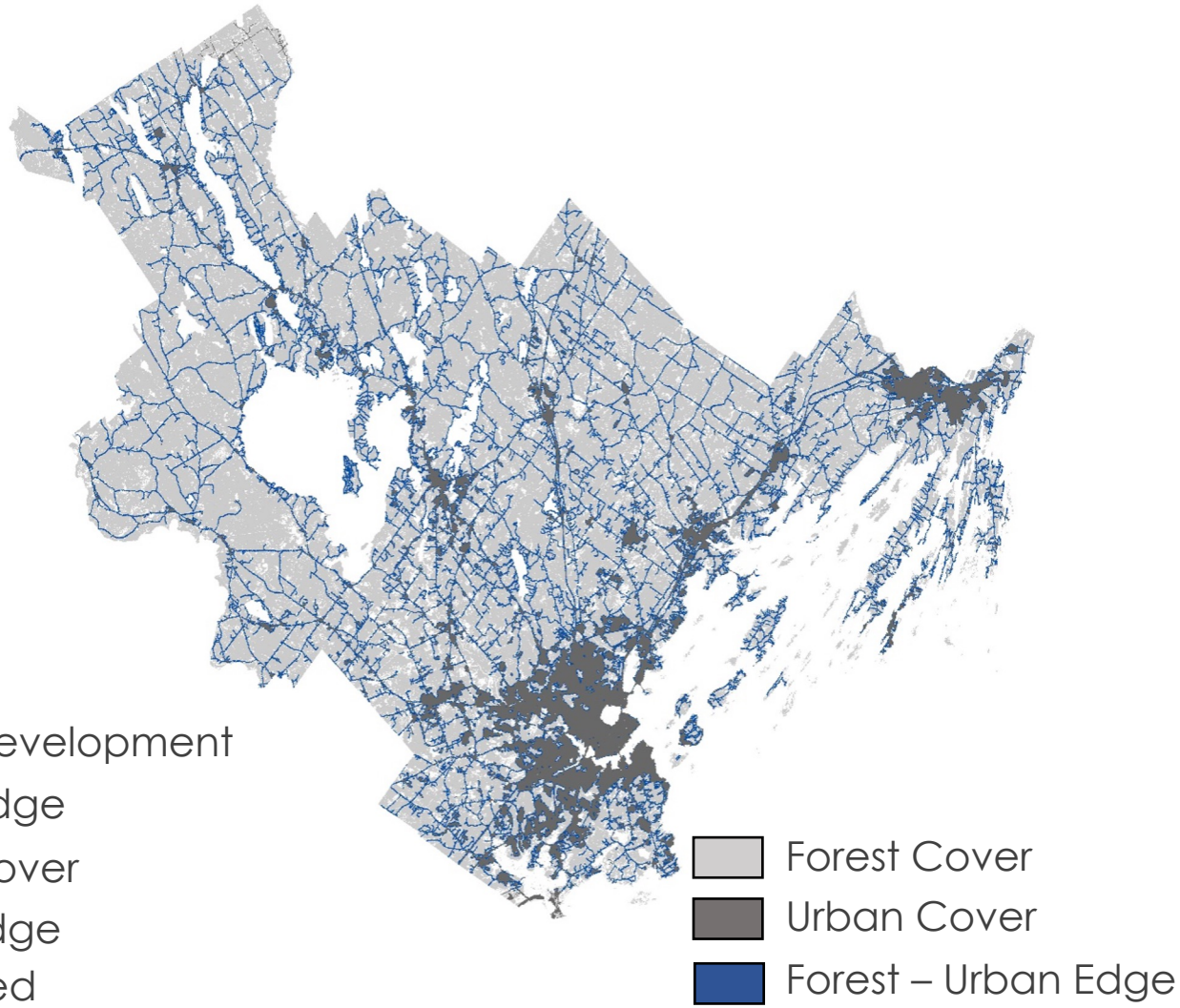


Example of mangrove extent mapping over a time series to track how mangrove presence has change over a 20-year period (from the exercises completed during the ARSET Mangrove Mapping series).
Image Credit: NASA ARSET

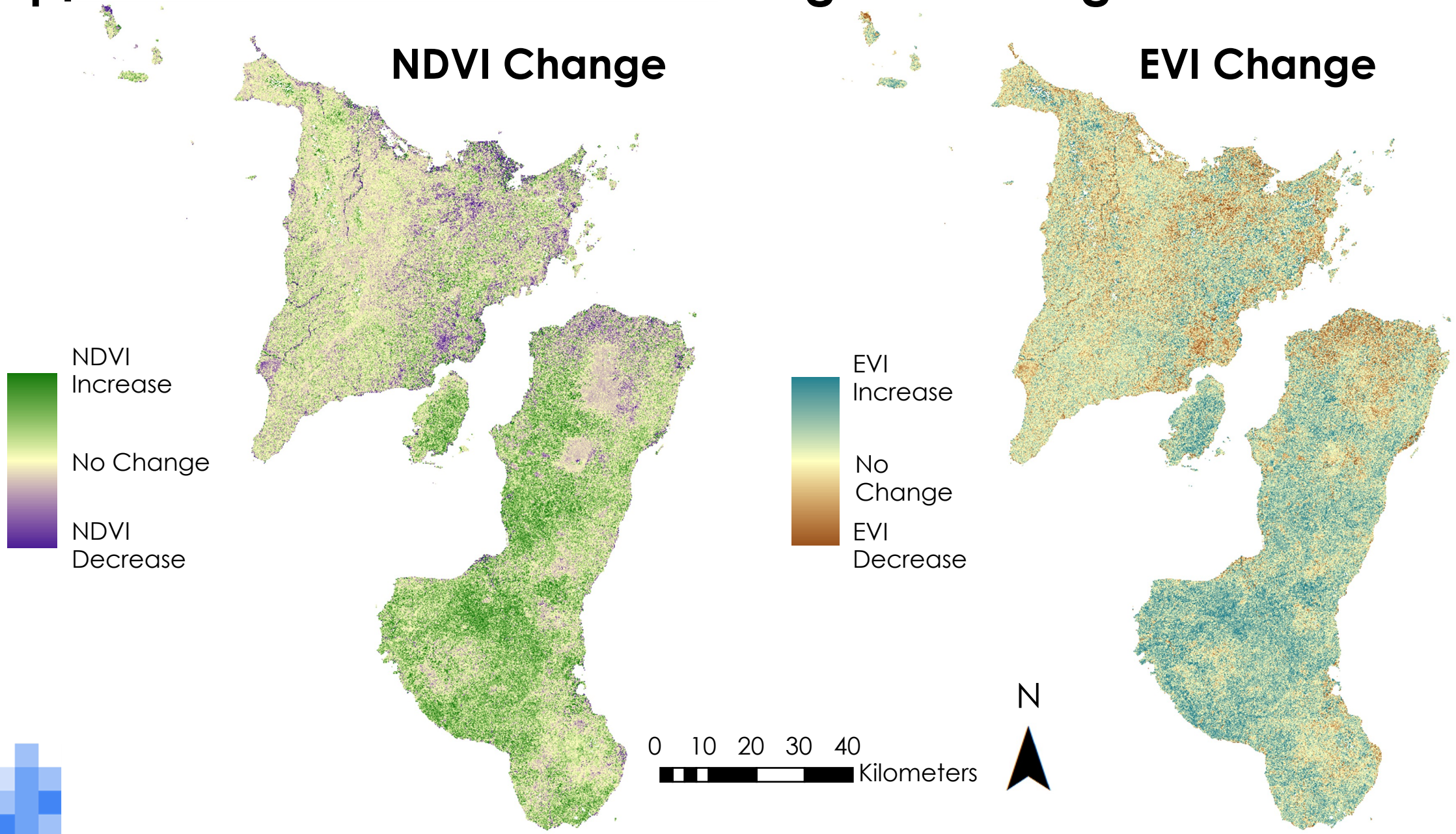
Visit the Data Explorer and Comparison Apps for more information on mangrove mapping and apps in GEE.

Applications of GEE for Land Management: Land Cover



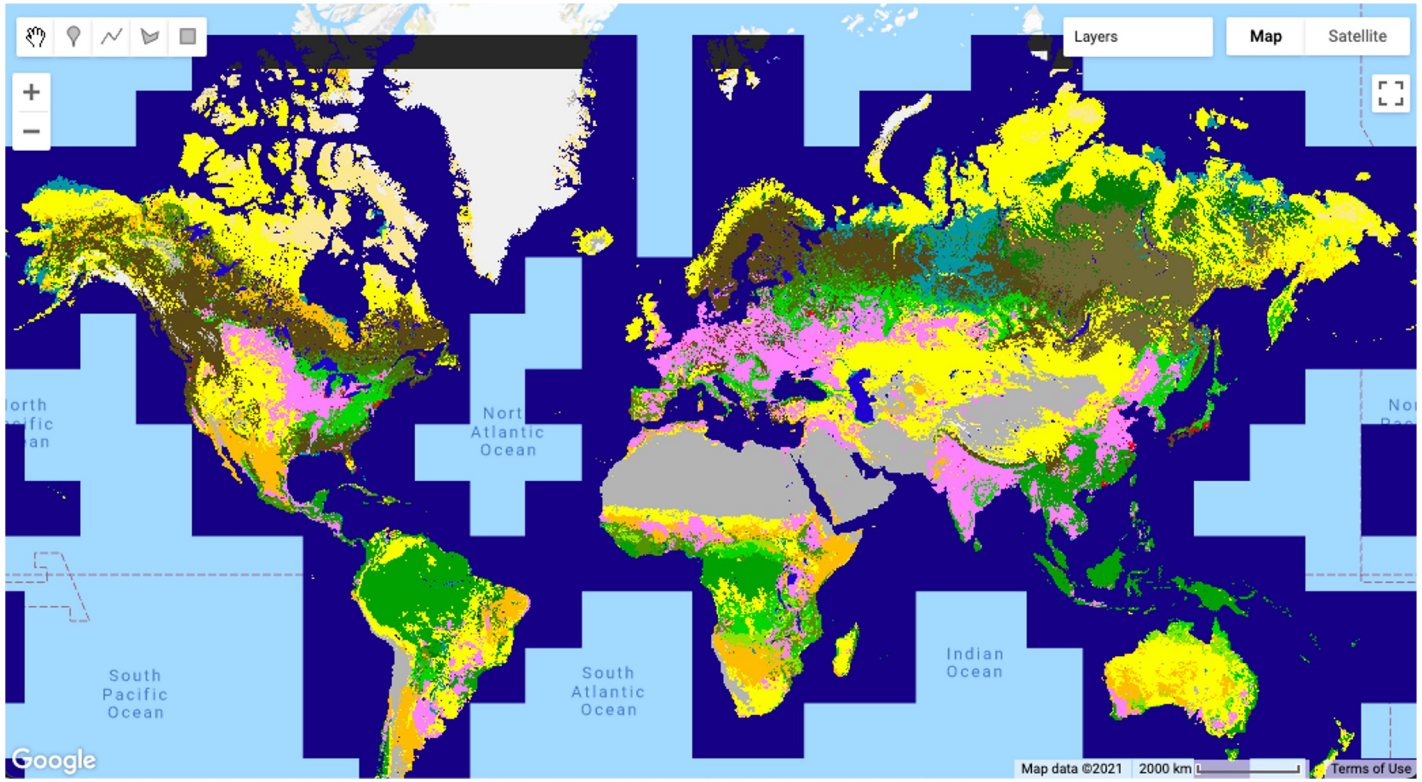


Applications of GEE for Land Management: Vegetation Indices

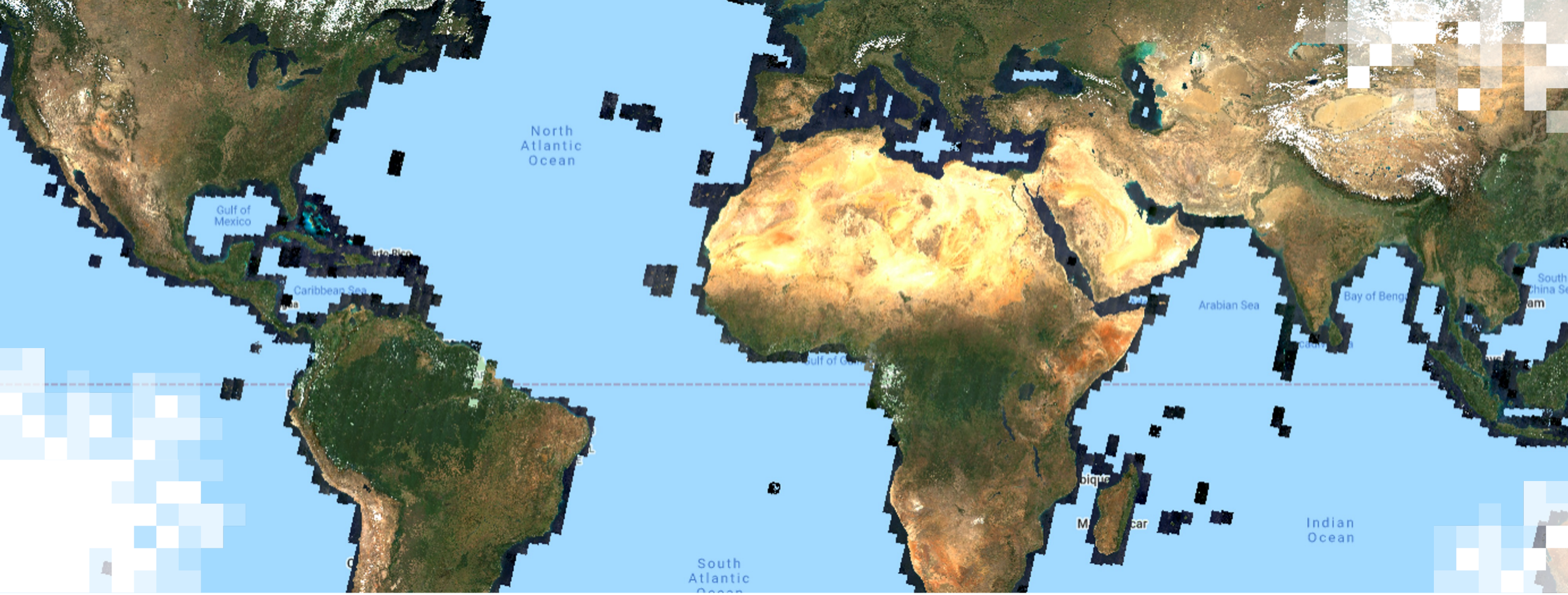


Available Satellite Sensor Data in GEE: Land Cover Products

- A variety of land cover data products are available in GEE, including:
  - ESA WorldCover 10m v200
  - MODIS Land Cover Type Yearly Global 500m
  - Global PALSAR-2/PALSAR Forest/Non-Forest Map
  - USGS National Land Cover Database
- GEE Data Catalog:
  - https://developers.google.com/earth-engine/datasets/tags/landcover



Copernicus Global Land Cover Layers: CGLS-LC100 collection 3 displayed globally in GEE. Credit: Earth Engine Data Catalog



Demo – Land Cover Acquisition

ESA WorldCover 10m v100

- Code for demo: https://code.earthengine.google.com/7cba979b0b54d16e8a01e2bf53e426c2
- Dataset (GEE): https://developers.google.com/earth-engine/datasets/catalog/ESA_WorldCover_v100
- Dataset Availability
  - 2020-01-01 to 2021-01-01
- Dataset Provider
  - ESA/VITO/Brockmann Consult/CS/GAMMA Remote Sensing/IIASA/WUR
- Description
  - The European Space Agency (ESA) WorldCover 10 m 2020 product provides a global land cover map for 2020 at 10 m resolution based on Sentinel-1 and Sentinel-2 data. The WorldCover product comes with 11 land cover classes and has been generated in the framework of the ESA WorldCover project, part of the 5th Earth Observation Envelope Programme (EOEP-5) of the European Space Agency.

Summary

- The GEE platform provides users with cloud-based computing resources that can decrease barriers like data storage space and personal computing power.
- The capabilities of GEE are similar to those of many GIS platforms used to manipulate satellite data for key land-related remote sensing processes, including algorithm application and land cover classification.
- GEE hosts many datasets relevant to land monitoring.
  - Landsat Series, MODIS, Sentinel-2, and Sentinel-1 SAR
- The JavaScript API enables coding and automation of basic remote sensing functions like imagery filtering, and vegetation index calculation.
- Users interested in the Python API can explore Google Colab.
- Session 2: Land Cover Classification & Accuracy Assessment

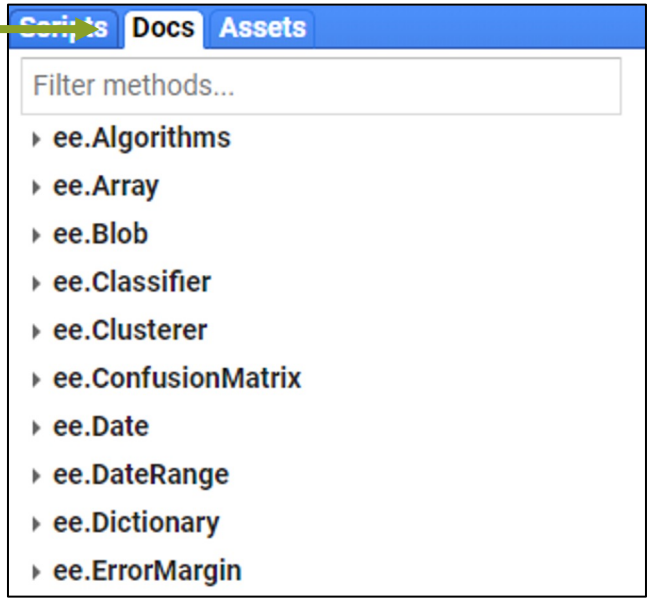
Resources for Help

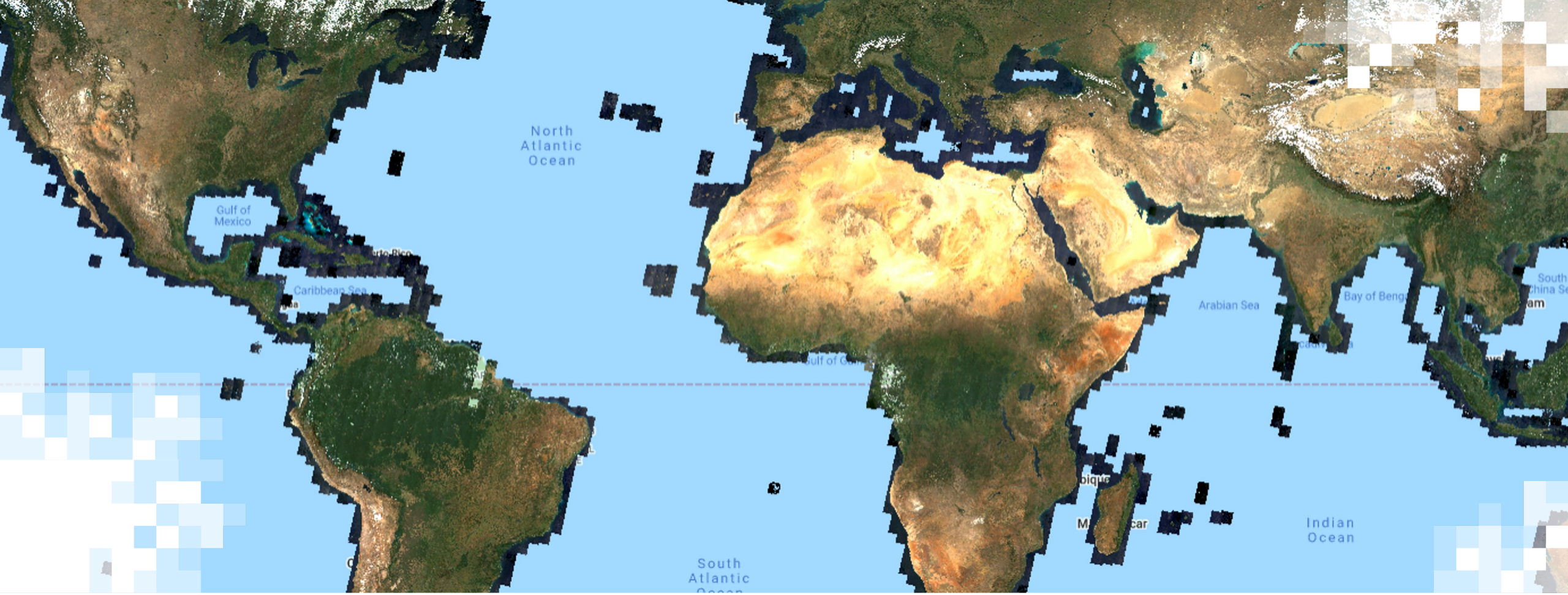
Using Google Earth Engine for Land Monitoring Applications:

- https://appliedsciences.nasa.gov/join-mission/training/english/arset-using-google-earth-engine-land-monitoring-applications

Forest Mapping and Monitoring with SAR Data

- https://appliedsciences.nasa.gov/join-mission/training/english/arset-forest-mapping-and-monitoring-sar-data
- Docs Tab
- Developer's Guide
- Google Earth Engine Developers Group





Demo – Surface Water Acquisition

JRC Global Surface Water Mapping Layers, v1.4

- Code for demo: https://code.earthengine.google.com/accaae70c708e041d994d0bf762430d7
- Dataset (GEE): https://developers.google.com/earth-engine/datasets/catalog/JRC_GSW1_4_GlobalSurfaceWater
- Dataset Availability:
  - 1984-03-16 to 2022-01-01
- Dataset Provider:
  - EC JRC / Google
- Description:
  - This dataset contains maps of the location and temporal distribution of surface water from 1984 to 2021 and provides statistics on the extent and change of those water surfaces. For more information see the associated journal article: High-resolution mapping of global surface water and its long-term changes (Nature, 2016) and the online Data Users Guide. These data were generated using 4,716,475 scenes from Landsat 5, 7, and 8 acquired between 16 March 1984 and 31 December 2021.

Resources for Help

Using Google Earth Engine for Water Resources Applications:

- https://developers.google.com/earth-engine/datasets/tags/surface

Using Earth Observations to monitor Water Budgets for River Basin Management:

- https://appliedsciences.nasa.gov/join-mission/training/english/arset-using-earth-observations-monitor-water-budgets-river-basin-0

Mapping and Monitoring Lakes and Reservoirs with Satellite Observations:

- https://appliedsciences.nasa.gov/join-mission/training/english/arset-mapping-and-monitoring-lakes-and-reservoirs-satellite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Thank You!