

# Water Classification of Satellite Imagery Using Python and ArcGIS Pro

Master of GIS | Capstone Project at Penn State University

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# Master's Capstone Project

- The water classification script/tool was developed for an Advanced Python for GIS course at Penn State University
- The goal of my capstone project will be to create an ArcGIS Notebooks walkthrough of a section of the code
  - The notebook will have an educational and tutorial purpose and allow readers to run code and visualize the results
- Readers of the notebook will learn how to fuse remote sensing analysis and Python coding



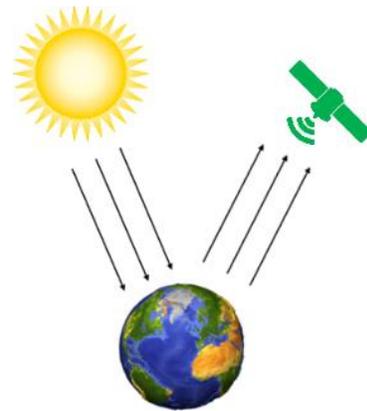
**PennState**



# Remote Sensing Basics

## Passive

- Only receive incoming radiation reflectance
- Operate on principles of Electromagnetic (EM) radiation
- Require the sun's radiation to collect information
- Can only collect imagery in Daylight



Passive Remote Sensing

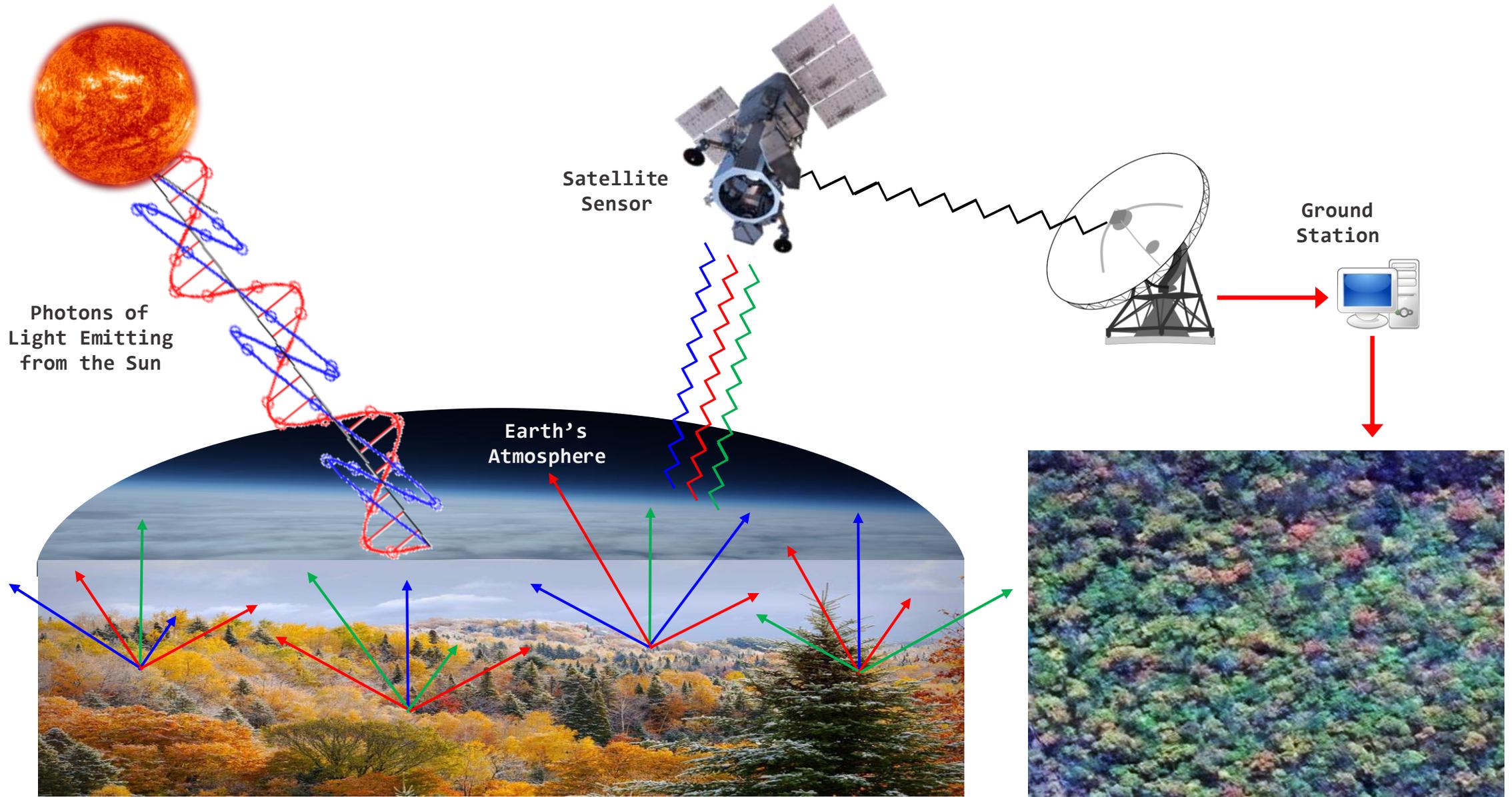
## Active

- Emit their own radiation and record the reflectance:
  - Light as lasers (LiDAR)
  - Radio waves (Radar)
  - Sound waves (Sonar)
- Based on the principles of the EM spectrum.
- Do not require the sun's radiation as they emit their own.
- Can collect imagery at night!



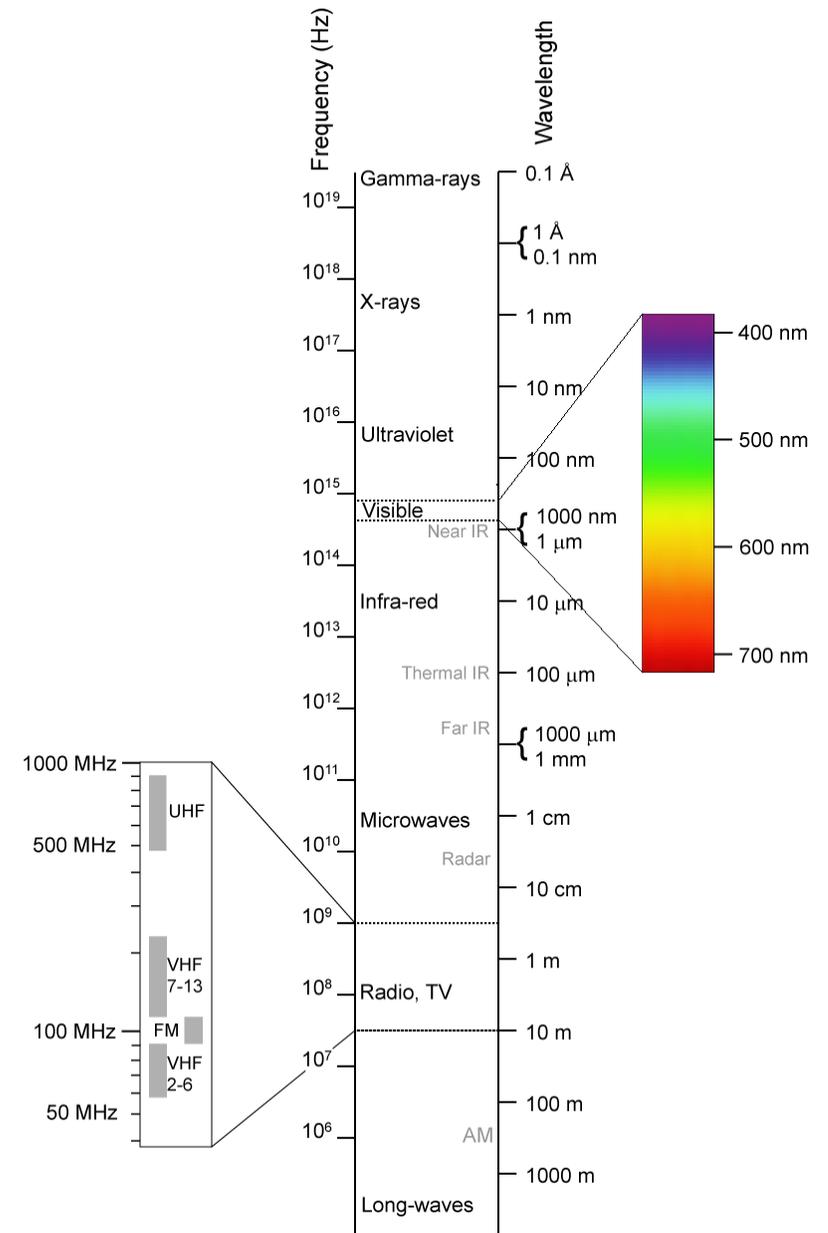
Active Remote Sensing

# Passive Sensors



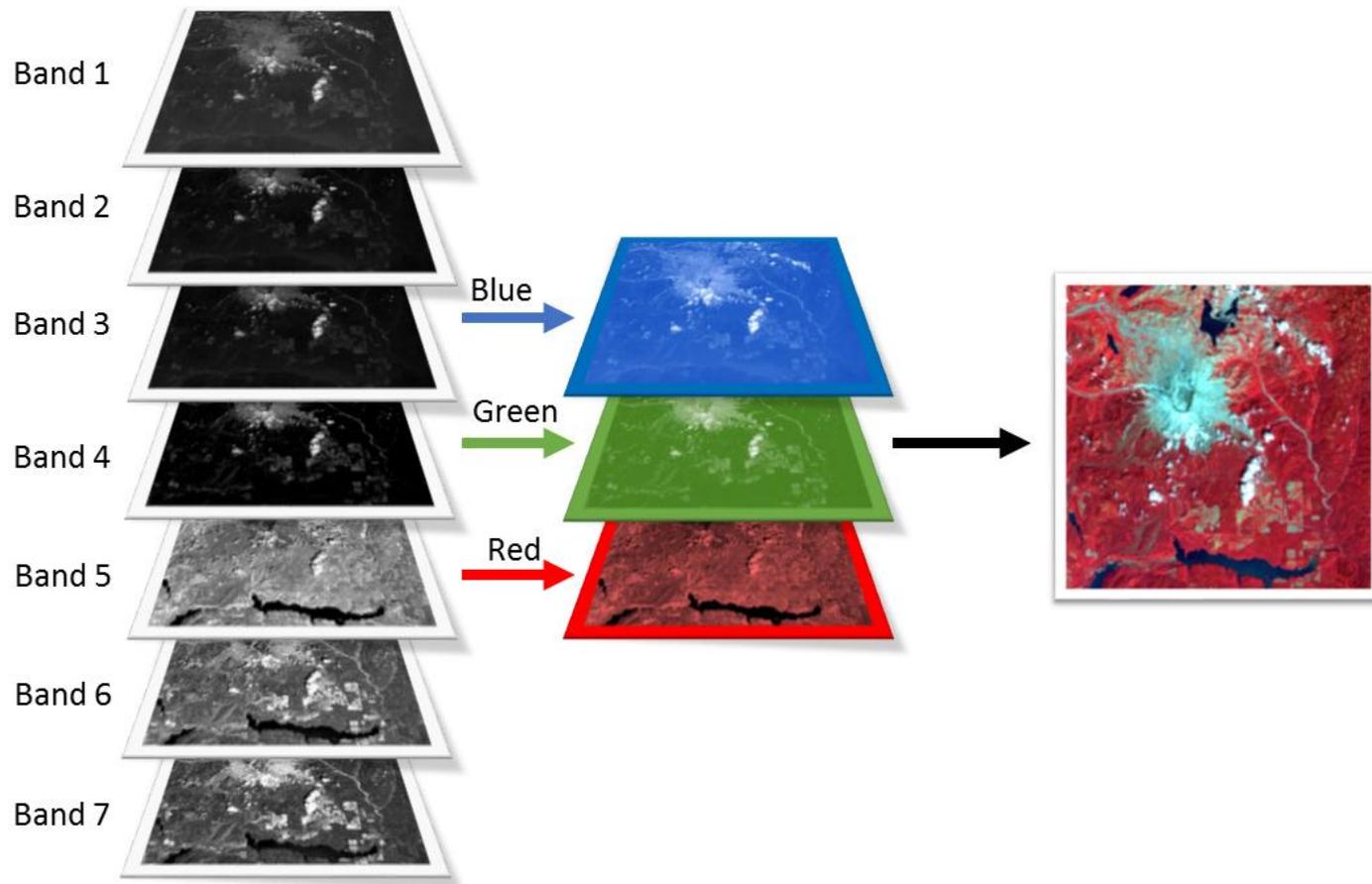
# Principles of Electro-Optical (EO) Sensors

- The Electromagnetic (EM) Spectrum is the scientific principle all Remote Sensing is based on
- Human eyes can see a very narrow spectrum of light, known as the “Visible” range
- Satellite sensors collect data in different “bands”, which are simply small subsets of the EM spectrum. These are measured in wavelength ( $\lambda$ )
- EO sensors are able to “see” areas of the spectrum that humans cannot. This is often referred to as “Multi-Spectral” or “MS” imagery
- **Spectral Resolution** is a descriptive term used to characterize the number and width of bands that a sensor is able to collect data on
  - More bands with a finer width = higher Spectral Resolution



What can we do with  
different bands?

# Band Combinations



## Common Band Combinations

### Natural Color:

Red = Red Band

Green = Green Band

Blue = Blue Band

### False Color Infrared:

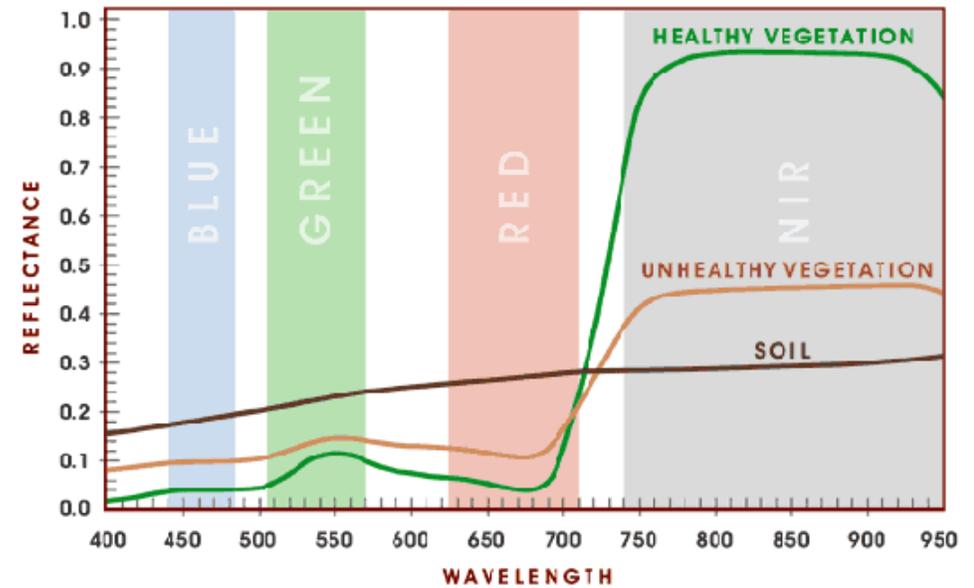
Red = Near Infrared Band

Green = Red Band

Blue = Green Band

# Spectral Indices

- Spectral Indices are essentially mathematical formulas which take advantage of the reflective properties of various materials
- These indices, which number in the hundreds, are used to analyze and identify things such as:
  - Vegetation
  - Water
  - Man-made areas
  - Burned areas
- One common index is the Normalized Difference Vegetation Index (NDVI), and is calculated by using the following formula:
$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$
- The NDVI takes advantage of the fact that vegetation, and specifically healthy vegetation reflect high amounts of Near Infrared (NIR)



NDVI change analysis of agricultural fields.

What problem is my  
tool solving?

# Problem: Standing Water

Identifying standing water is an important task for many geospatial and remote sensing scientists

Supports **natural disaster** relief and response efforts:

Identifying flooded areas post disaster. Allowing better allocation of resources



Supports **disease eradication** and research efforts:

Many insect borne diseases are transmitted by insects who breed in standing water. Ex: Malaria, West Nile virus, and Dengue



How can we approach and solve  
the problem using remote  
sensing technologies?

# Tool Overview

The tool classifies satellite imagery to identify and map standing water

- Python tool utilizing various packages including ArcPy
  - Able to be run in python via Command Line or IDE
  - An ArcToolBox Script tool was also created, allowing the tool to be run within ArcGIS Pro
  - Utilizes spectral indices and automatic thresholding to identify water
- Outputs the classified water in both raster and vector formats
- Currently works for:
  - Maxar's WorldView-2 & WorldView-3
  - European Space Agency's Sentinel-2



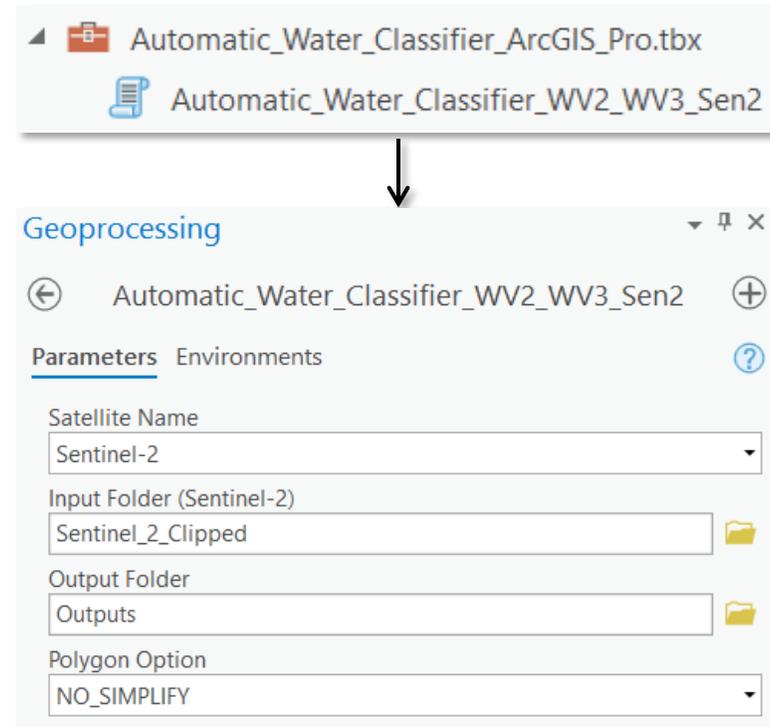
**ArcGIS Pro**

# Tool Format

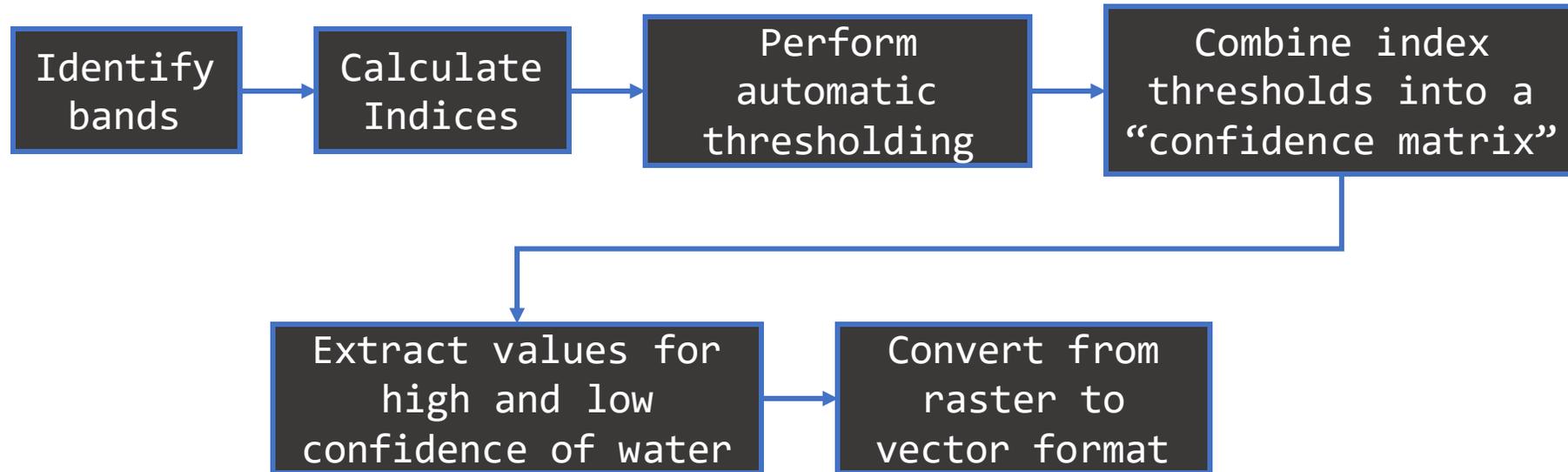
Currently the tool is in the format of two Python script files. These files contain the processing functions necessary to perform the classification (Shown Left)

```
Processors.py x Automatic_Water_Classifier.py x
1  # This script was developed by Daniel Clement - 2021
2  # Python 3.7
3  """
4  This script contains many of the processes required for the Automatic Water Classifier script
5  """
6
7  # import packages
8  import os
9  import arcpy
10 from arcpy.sa import *
11 from glob import glob
12
13
14 class DefineBands:
15     """
16     defines a class which will contain the methods that will create the variables that hold the paths to the various
17     bands that will be used in the band index calculations
18     """
19     # creates band variables for WorldView-2 or WorldView-3 imagery
20     def create_wv2_wv3_band_variables(self, in_image):
21         arcpy.AddMessage("Creating variables for image bands...")
22
23         # create the variables for the bands in the input image file
24         # input image file needs to have all 8 bands composited as one single image file
25         # this is how WorldView imagery is commonly delivered from the factory when ordered
26         Coastal_Blue = in_image + "\\Band 1"
27         Blue = in_image + "\\Band 2"
28         Green = in_image + "\\Band 3"
29         Yellow = in_image + "\\Band 4"
30         Red = in_image + "\\Band 5"
31         Red_Edge = in_image + "\\Band 6"
32         NIR1 = in_image + "\\Band 7"
33         NIR2 = in_image + "\\Band 8"
34         return Coastal_Blue, Blue, Green, Yellow, Red, Red_Edge, NIR1, NIR2
```

Also built for the tool is integration with an ArcToolbox Script Tool allowing the tool to be used within a GUI interface in ArcGIS Pro (Shown Right)



# Tool Process Workflow

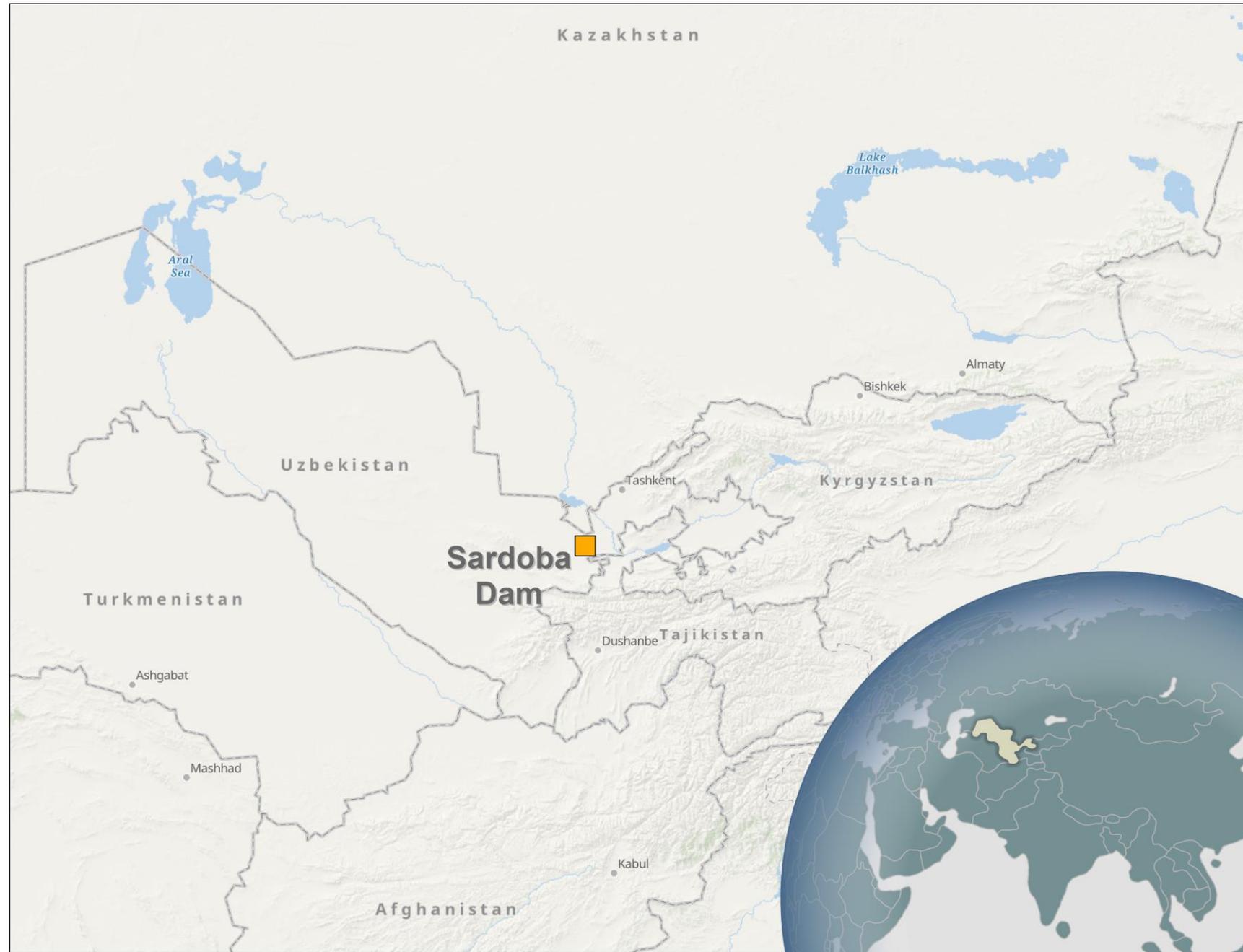


# Case Study: Sardoba dam, Uzbekistan

In April of 2020, the Sardoba dam suffered a breach in its containing wall, the subsequent flood of water inundated large areas of the surrounding land



Sardoba Dam Breach. Image Source: kun.uz



Map by: Daniel Clement

# Before Dam Breach – February 4, 2020

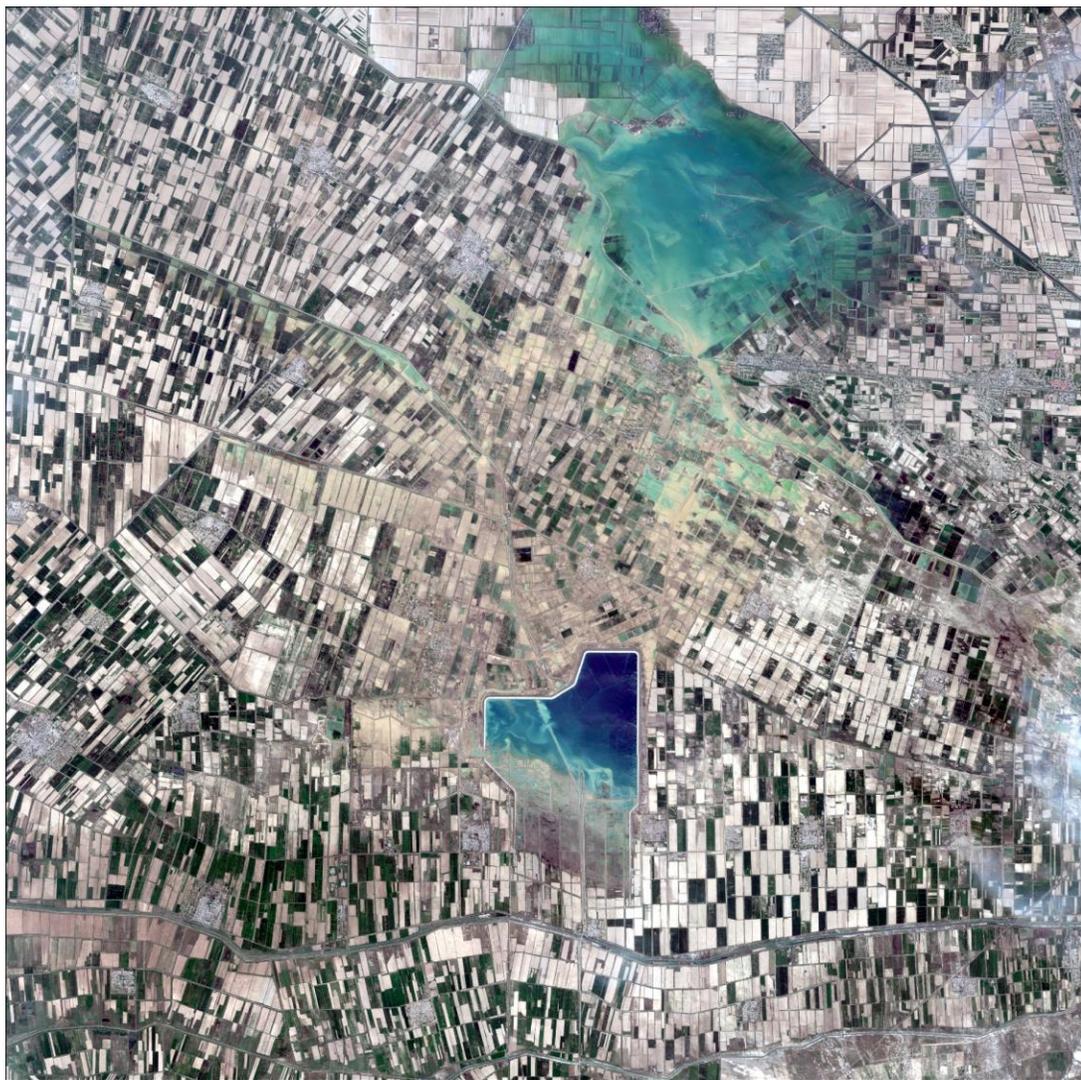


Natural Color imagery of Sardoba Dam - Sentinel-2

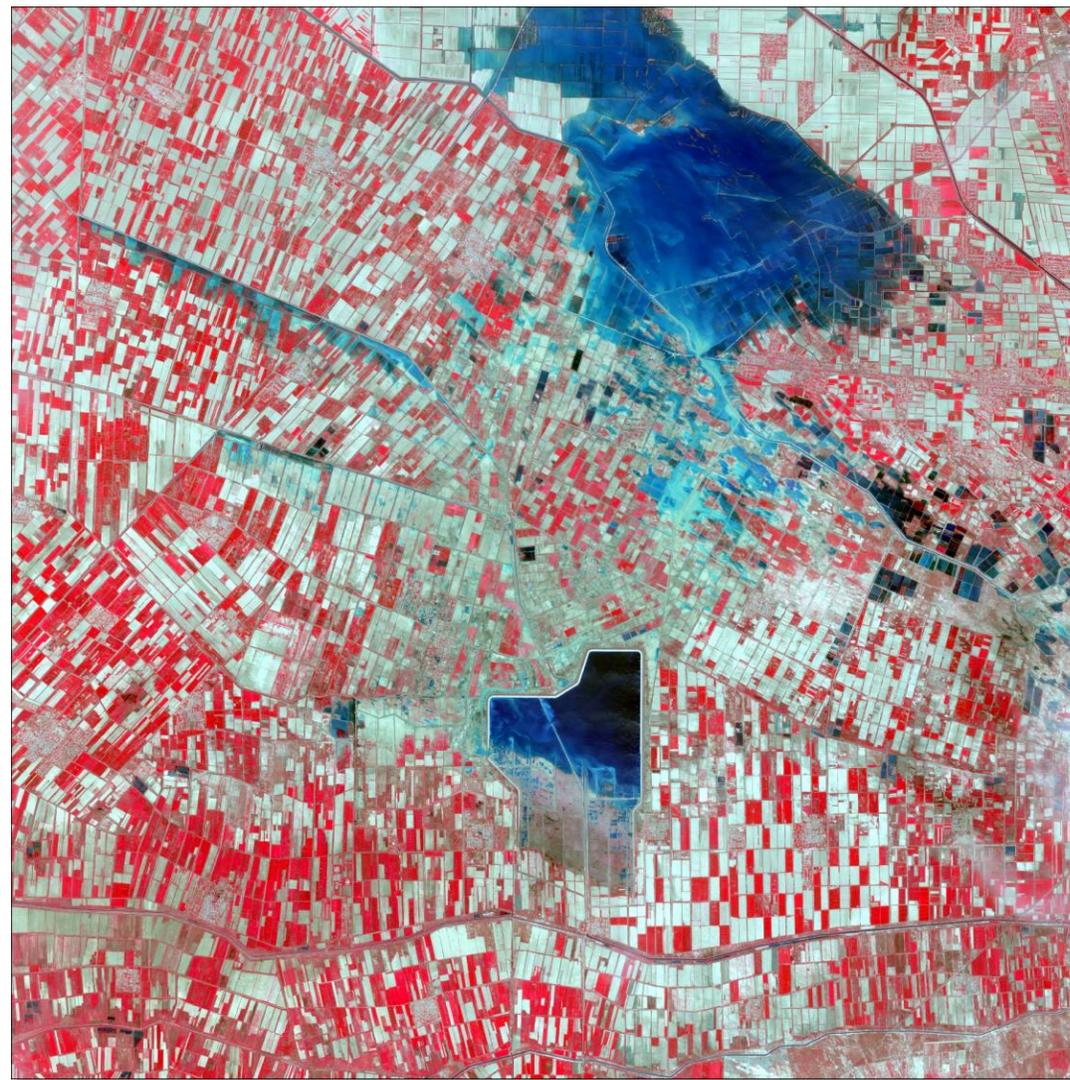


False Color Infrared imagery of Sardoba Dam - Sentinel-2

# After Dam Breach - February 4, 2020



Natural Color imagery of Sardoba Dam - Sentinel-2



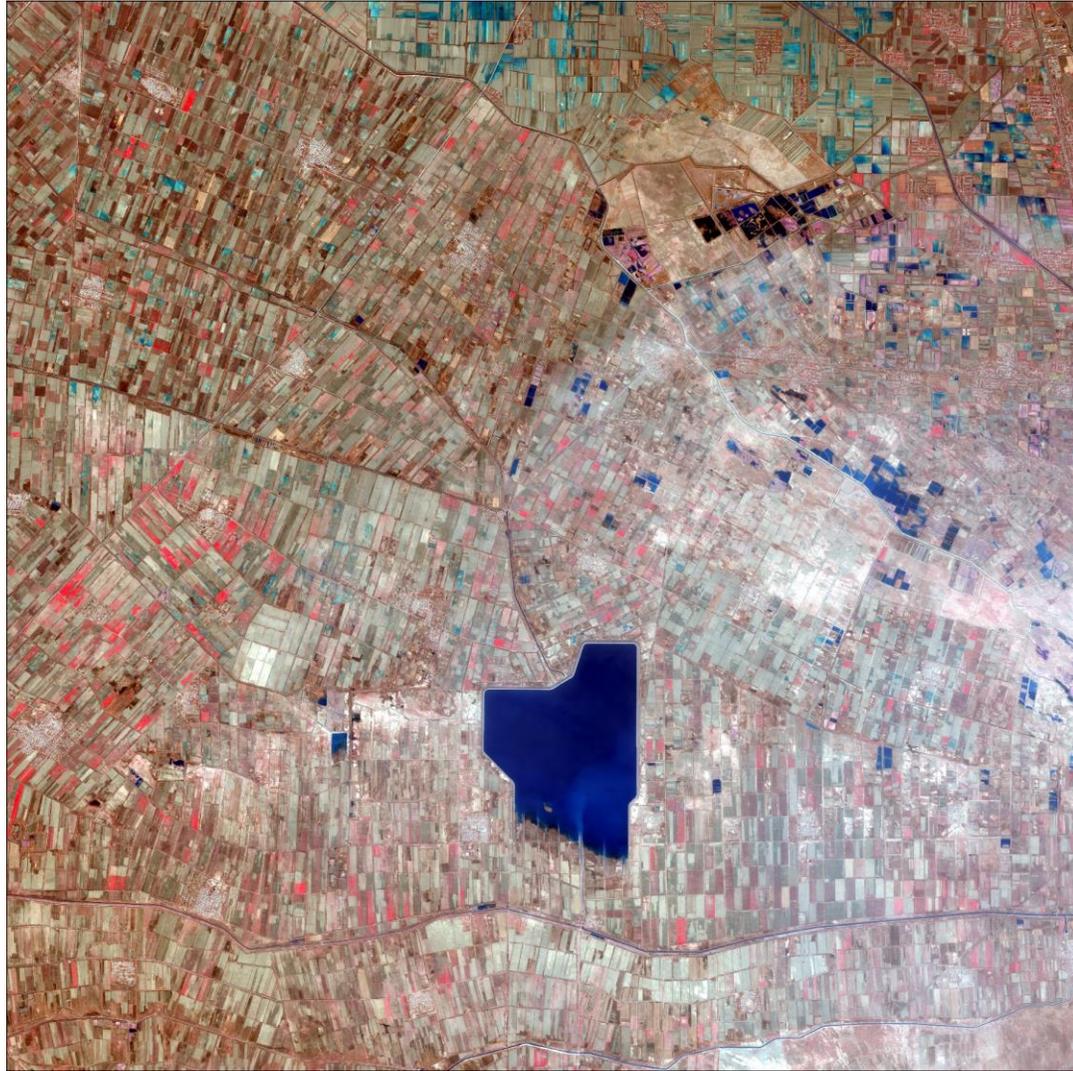
False Color Infrared imagery of Sardoba Dam - Sentinel-2

# After Dam Breach – February 4, 2020

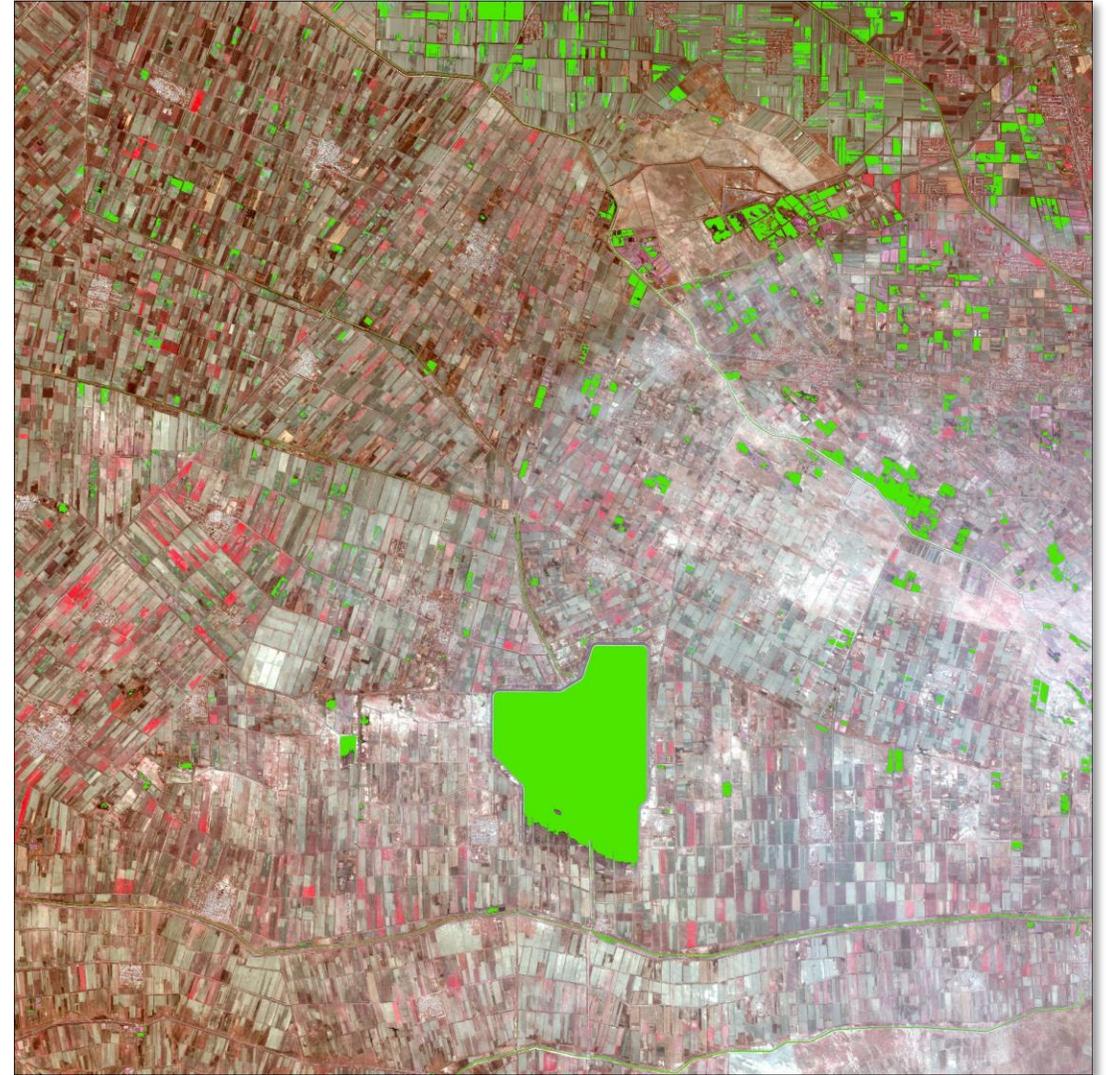


Sardoba Dam breach - Sentinel-2

# Before Dam Breach – February 4, 2020

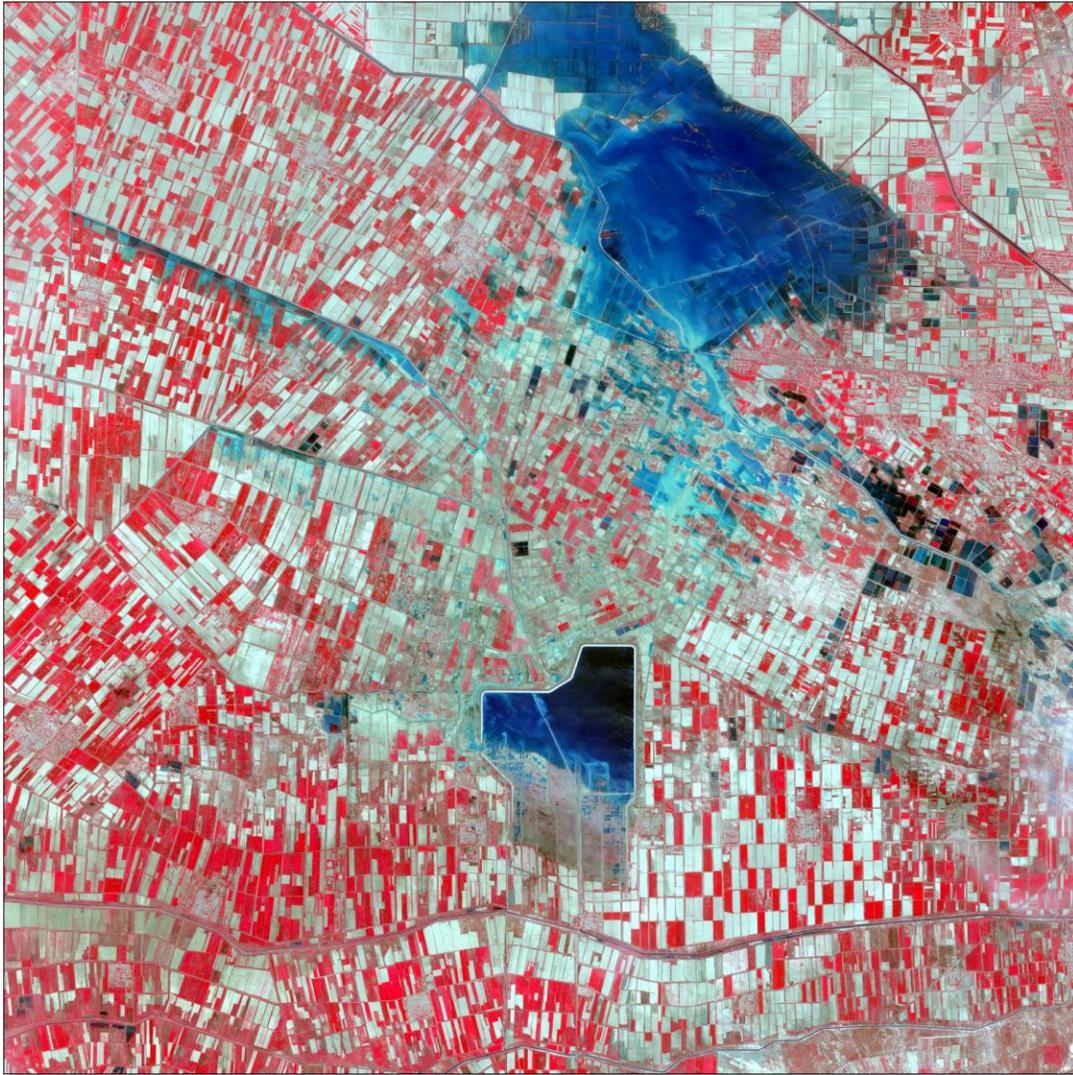


False Color Infrared imagery of Sardoba Dam - Sentinel-2

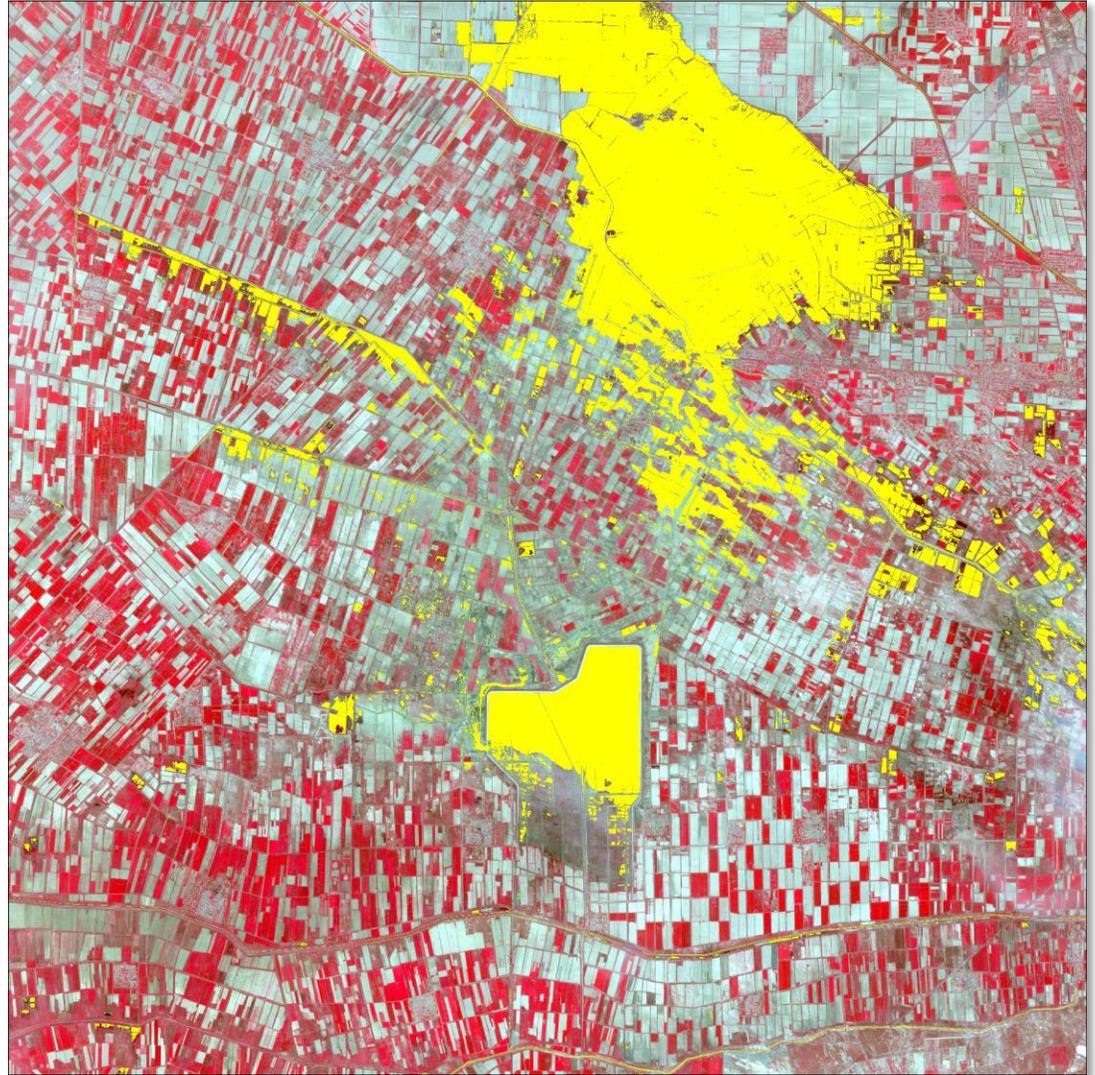


Areas Classified as Water – Shown in Green

# After Dam Breach – February 4, 2020



False Color Infrared imagery of Sardoba Dam - Sentinel-2

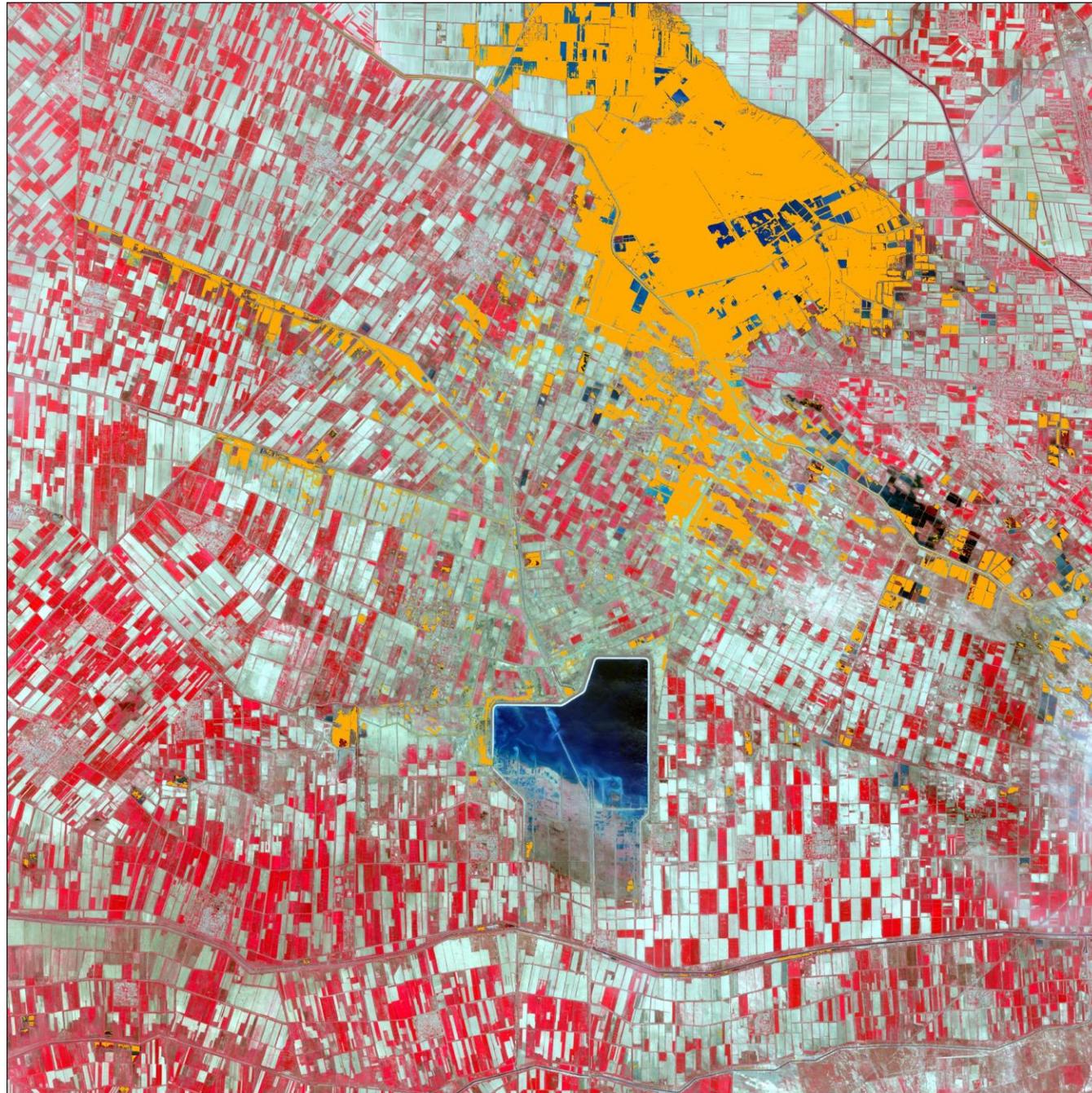


Areas Classified as Water – Shown in Yellow

# Applications

## Change

Areas where water existed before, are removed from the After water area. This analysis results in a raster containing only the areas which are new waterbodies or inundated areas.



Areas Classified as New Water (change) – Shown in Orange

# Next Steps?

- Identify the section of the code which will be used for the ArcGIS Notebook
- Build out the notebook
- Share with colleagues and fellow students.

Import IPython Widgets and Display

```
In [ ]: !conda install jupyter_dashboards -c conda-forge -y
```

```
In [1]: from ipywidgets import widgets
        from IPython.display import clear_output
```

Connect to ArcGIS Online and Access the Landsat Services

```
In [2]: from arcgis.gis import GIS
        from arcgis.raster.functions import *

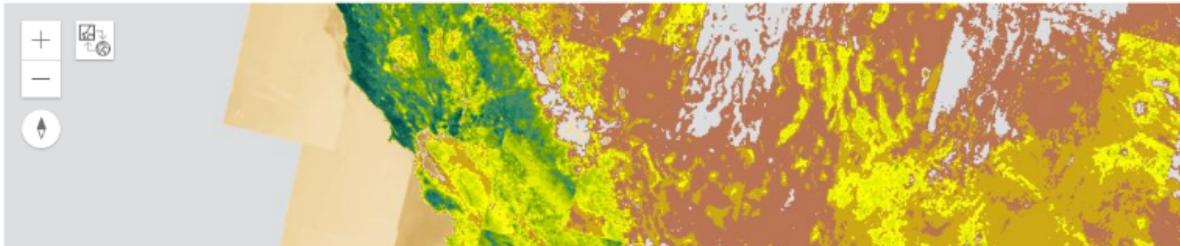
        gis = GIS()

        landsat_item = gis.content.search("Landsat Multispectral tags:'Landsat on AWS','landsat 8',
        'Multispectral', 'Multitemporal', 'imagery', 'temporal', 'MS'', 'Imagery Layer')[0]
        landsat = landsat_item.layers[0]
```

Create a Map and Add Landsat Layers

```
In [1]: map1 = gis.map("California, USA")
        map1
```

Out[1]:



Example Jupyter Notebook – Source: [esri.com](https://esri.com)

An aerial photograph of a vast agricultural landscape, likely a rice paddy field, characterized by a dense grid of rectangular plots. The plots are colored in various shades of red, white, and yellow, suggesting different stages of crop growth or different types of crops. A prominent feature is a large, dark blue pond or reservoir located in the lower central part of the image, outlined in white. A dark grey rectangular box is superimposed over the center of the image, containing the word "Questions?" in white text.

Questions?