

Image Analysis for Defense and Intelligence

Official Esri Training Courseware



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Image Analysis for Defense and Intelligence

STUDENT EDITION

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Course version 4.0. Version release date July 2026.

Printed in the United States of America.

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Esri resources

Take advantage of these resources to develop ArcGIS® software skills, discover applications of geospatial technology, and tap into the experience and knowledge of the ArcGIS community.

Instructor-led and e-Learning resources

Esri® instructor-led courses and e-Learning resources help you develop and apply ArcGIS skills, recommended workflows, and best practices. View all training options at **esri.com/training/catalog/search**.

Planning for organizations

Esri training consultants partner with organizations to provide course recommendations for job roles, short-term training plans, and workforce development plans. Contact an Esri training consultant at **training@esri.com**.

Esri technical certification

The Esri Technical Certification Program recognizes qualified individuals who are proficient in best practices for using Esri software. Esri exams are designed to validate expertise with ArcGIS products, such as ArcGIS Online, ArcGIS Pro and extensions, ArcGIS Enterprise and extensions, and developer technologies. Certifications are offered at three levels: foundation, associate, and professional. Learn more at **esri.com/training/certification**.

Social media and publications

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Esri on LinkedIn: **linkedin.com/company/esri**

Esri training blog: **esri.com/trainingblog**

Esri publications: Access online editions of ArcNews, ArcUser, and ArcWatch at **esri.com/esri-news/publications**

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Esri resources (continued)

Esri Press

Esri Press publishes books on the science and technology of GIS in numerous public and private sectors. **esripress.esri.com**

GIS bibliography

A comprehensive index of journals, conference proceedings, books, and reports related to GIS, including references and full-text materials. **gis.library.esri.com**

ArcGIS documentation and tutorials

In-depth information, tutorials, and documentation for ArcGIS products.

ArcGIS Online: **arcgis.com**

ArcGIS Enterprise: **enterprise.arcgis.com**

ArcGIS Pro: **pro.arcgis.com**

Esri Community

Join the online community of GIS users and experts. **community.esri.com**

Esri events

Esri conferences and user group meetings offer a great way to network and learn how to achieve results with ArcGIS. **esri.com/events**

Esri videos

View an extensive collection of videos by Esri leaders, event keynote speakers, and product experts. **mediaspace.esri.com**

Esri resources (continued)

ArcGIS for Personal Use

Improve your GIS skills at home and use ArcGIS to enhance your personal projects. The ArcGIS for Personal Use program includes a 12-month term license for ArcGIS Pro, extension products, and an ArcGIS Online named user account with 100 service credits. **esri.com/personaluse**

GIS Dictionary

This term browser defines and describes thousands of GIS terms. **support.esri.com/en-us/gis-dictionary**

Course introduction

Imagery has been an important part of intelligence and military operations for many years. As the availability and sophistication of commercial imagery improved, its application for defense use increased and improved, as well. The Image Analyst extension in ArcGIS Pro allows you to use these improvements and incorporate imagery into your current intelligence preparation of the operational environment workflows.

In this course, you will learn the skills to visualize, analyze, and exploit imagery for use in your current geospatial intelligence (GEOINT) workflow processes. You will learn how to use various types of imagery formats to solve and answer intelligence questions.

Course goals

After completing this course, you will be able to perform the following tasks:

- Choose appropriate imagery datasets for a given scenario and area of interest.
- Gain insight into processing techniques for a variety of imagery formats, including synthetic aperture radar (SAR) data, and factors that impact the accuracy of imagery interpretation.
- Apply ArcGIS capabilities to enhance imagery display, accurately measure features on oblique and vertical imagery, and analyze change.
- Perform image classification and analyze geospatial video to categorize land-cover features and identify areas and objects of interest.

Installing the course data

Some exercises in this workbook require data. Depending on the course format, the data is available on a DVD in the back of a printed workbook or as a data download. To use the data, extract it to your C:\EsriTraining folder.



DISCLAIMER: Some courses use sample scripts or applications that are supplied on the internet. These samples are provided "AS IS," without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose, or noninfringement. Esri and its authorized distributors shall not be liable for any damages under any theory of law related to the licensee's use of these samples, even if Esri and its authorized distributors are advised of the possibility of such damage.

Icons used in this workbook



Notes indicate additional information, exceptions, or special circumstances about specific course topics.



Recommended practices improve efficiency and save time.



Esri Academy resources provide more in-depth training on related topics.



Additional resources provide additional information about related topics.



Warnings indicate potential problems or actions that should be avoided.

Knowing imagery terminology and how imagery is organized in ArcGIS Pro is essential to conducting effective analysis. Quickly identifying what each item is in the Catalog pane and knowing how to manipulate bands to expose the information that you are trying to extract from the imagery that you have obtained are critical skills for imagery analysis. In this lesson, you will learn about ArcGIS Pro terminology associated with imagery and how imagery is organized in ArcGIS Pro.

Topics covered

- Accessing imagery in ArcGIS Pro

- Working with imagery bands

Imagery for military applications

Imagery used by the military or intelligence agencies comes in many forms. In addition to various government collection platforms dedicated to defense use, militaries will also use commercially available imagery when appropriate and cost-effective. The type of mission or problem set will often dictate the type of imagery used for various applications or analysis workflows.

Imagery example



Description

Landsat 8

- Western Australia
(February 2, 2019)
- False color infrared (IR) composite
- Potential uses can include the following:
 - Broad area surveys
 - Area familiarization (strategic or operational)
 - Small-scale image maps



WorldView-3

- Kukawa, Nigeria
(January 1, 2019)
- Panchromatic imagery
- Potential uses can include the following:
 - Detailed maps
 - Mission planning

Imagery for military applications (continued)

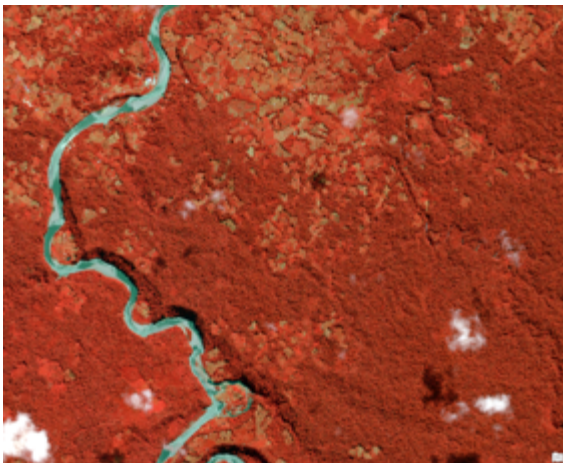
Imagery example



Description

WorldView-2

- Border of Colombia and Ecuador (June 23, 2017)
- Natural color composite
- Potential uses can include the following:
 - Realistic image maps
 - Land-cover and land-use assessments
 - Area familiarization (operational or tactical)



WorldView-2

- Border of Colombia and Ecuador (June 23, 2017)
- False color IR composite
- Potential uses can include the following:
 - Vegetation analysis
 - Land-cover assessments



WorldView-3

- New Orleans, Louisiana, United States (November 15, 2018)
- Oblique view
- Potential uses can include the following:
 - Mission planning
 - Target packages and assessments
 - Enhanced mensuration of features

Imagery for military applications (continued)

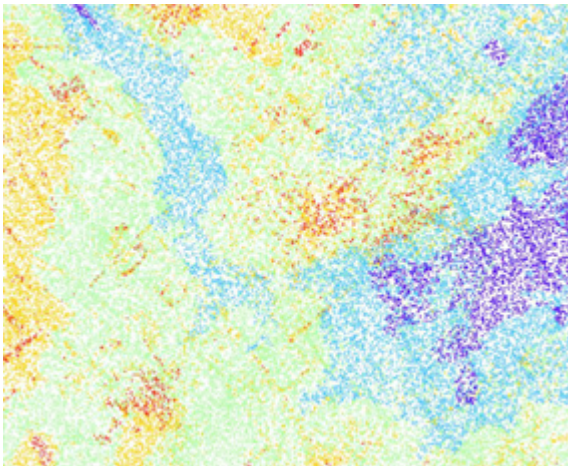
Imagery example



Description

Geospatial video

- Cheyenne, Wyoming, United States
- Image and video clip capture
- Potential uses can include the following:
 - Real-time and near real-time situational awareness
 - Pattern of life observation



Lidar (light detection and ranging) point cloud

- Potential uses can include the following:
 - Mission planning
 - Create highly detailed elevation models
 - Feature extraction



Radar (radio detection and ranging) image

- Potential uses can include the following:
 - Create elevation models
 - Ship detection and tracking
 - All-weather surveillance

(Data source for images: U.S. Geological Survey, Maxar [Vantor], L3 Harris Technologies, City of Austin)

How is imagery used?

Observing and analyzing the world through images is informative and immediate. It can deliver stark visual evidence or reveal new insights. Some analysts use imagery extensively in their work while others use it sparingly. Many types of imagery are used by military analysts, and military applications using imagery vary greatly but can fall into certain broad categories.

What imagery data have you used?

For what purposes have you used imagery?

Types of imagery collection platforms

There are three primary types of imagery collection platforms: satellites, unmanned aerial vehicles (UAVs), and manned aircraft. Each of these platforms carries a sensor that collects imagery. Each platform has characteristics that affect the imagery that it collects. The following table compares some of these characteristics and provides example use cases for imagery collected by each platform.

Imagery collection platforms

Platform type	Timeliness	Collection area*	Processing factors	Use case
Satellite	Daily to yearly or longer	Large (77 km x 45 km)	Altitude, orbit	Target package, change over time, image classification
Manned aircraft	Real time, hourly, daily	Medium (1024 m x 1024 m)	Altitude, speed, collection type	Aerial reconnaissance
UAV	Real time, hourly, daily	Small (116 m x 87 m)	Altitude, speed, collection type	Near real-time motion imagery (for example, full-motion video support), lidar, short time change detection

*Sizes listed are examples; dimensions of each image from each platform can and will vary.

Imagery in ArcGIS Pro

ArcGIS Pro manages imagery for storage and analysis purposes in several ways. To effectively work with imagery, you must be able to describe the different formats and data models.

Raster product 	Provided by the vendor and uses sensor-specific metadata to ensure optimal display and orientation of the imagery. Uses processing templates created for the particular sensor collection platform to display specific band combinations and enhancements.
Raster function template	Result of multiple raster functions chained together, called a raster function chain. These processing chains are then saved out for use in analysis. These templates enable quick access to commonly used band combinations or processing chains.
Raster dataset 	Represents a basic image that is made up of one or more bands, where each band consists of an array of pixels and each pixel has a value.

Imagery in ArcGIS Pro (continued)

Mosaic dataset 	Data model for managing, displaying, sharing, and storing collections of rasters. The dataset is stored in a geodatabase and references file-based rasters on disk.
National Imagery Transmission Format (NITF) 	A container format that can store a variety of data types together, including images, ancillary data such as shapefiles and tables, and associated image support data (ISD). The United States Department of Defense (DoD) and Intelligence Community (IC) have standardized NITF to ensure that data products include everything needed to support a variety of exploitation workflows.



[ArcGIS Pro Help: Introduction to NITF data](#)

Choose the right imagery

ArcGIS Pro enables you to manage, visualize, and analyze many different types of raster data. An important first step in conducting imagery analysis is identifying what type of raster data that you have available. Viewing information about the rasters in the Catalog pane helps you to identify appropriate rasters for your work.

Instructions

- a** Start ArcGIS Pro.
- b** Click Open Another Project.
- c** In the Open Project dialog box, on the left, click This PC.
- d** Browse to **C:\EsriTraining\IMAD\Projects\Examine_Imagery** and open the Examine_Imagery project.
- e** In the Catalog pane, expand Folders, and then expand the Imagery folder.
- f** Use the data in the Imagery folder to answer the following questions.
- g** After you are finished, leave ArcGIS Pro open for the next activity.

1. How many raster datasets and raster products does the China folder contain?

2. Do you have imagery available in the China folder to conduct vegetation health analysis? Why or why not?

Choose the right imagery (continued)

3. How many NITF files are in the Colombia folder?

4. Give two examples of analysis that you can perform using bands in the raster dataset available in the Egypt folder.

Exercise 1

Assign spectral ranges



This scenario is completely fictitious in nature and should not be viewed as a representation of an actual operation.

You are tasked with obtaining imagery to support mission planning for operations in and around Aleppo, Syria. You will be producing various imagery products, including basemaps for Gridded Reference Graphic (GRG) creation, land-use analysis, briefing products, and others.

You have obtained WorldView-2 imagery with a spatial and temporal resolution that meets your requirements. However, the spectral ranges are not associated with the band numbers, making it difficult to use the imagery for analysis requiring different band combinations. You will prepare an image for use in analysis.

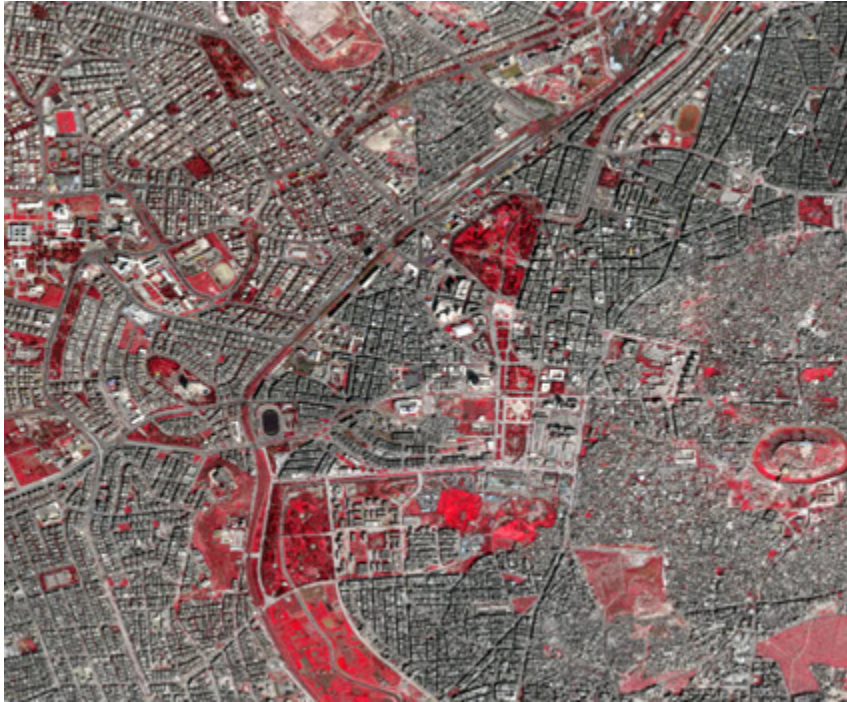
In this exercise, you will perform the following tasks:

- Assign descriptive names to band numbers in a raster dataset.
- Display an image in natural color.

Step 1: Review imagery

You will begin by reviewing the band information for the imagery that you have obtained.

- a Restore ArcGIS Pro, if necessary.
- b From the ribbon, click the Project tab.
- c Click Open, and then, on the right, click Open Another Project.
- d Browse to **C:\EsriTraining\IMAD\Projects\Syria**, and then open the Syria project.
- e If prompted to save changes to the previous project, click No.



When the project opens, the image is not displayed in natural color. You will change the bands associated with the red, green, and blue colors.

1. What is the band combination rendered for this image in your map?

- f In the Contents pane, select the Multispectral_16MAR23-M2AS_R3C2_P001_Bands.tif layer.

- g** From the Raster Layer tab, in the Rendering group, click Band Combination.

2. Which band combinations are available?

Remembering that a Natural Color band combination renders a Red, Green, and Blue composite, you decide to select this one.

- h** Choose Natural Color to change the band combination in your map.

3. What observation do you make about your image?

4. What is the band combination rendered for this image in your map?

- i** In the Catalog pane, expand Folders, the Imagery folder, and the Syria folder.

- j** Expand the 2016_0323(23MAR) folder, and then expand Multispectral_16MAR23-M2AS_R3C2_P001_Bands.tif.

You will notice that there are eight bands for the image. With eight bands, you expect that there should be more band combinations available than only Natural Color and Color Infrared. You will review the metadata to see if you can find more information.

- k** In the Contents pane, right-click Multispectral_16MAR23-M2AS_R3C2_P001_Bands.tif and choose Properties.

- l** In the Layers Properties dialog box, click the Source tab.

- m** Expand Band Metadata.

5. What is the spectral range—the minimum and maximum wavelengths in nanometers (nm)—for the Band_5 band?

You notice that none of the bands have band names associated for the spectral ranges.

- n Click OK to close the Layer Properties dialog box.

You can also find the spectral range for bands directly from the Contents pane.

- o In the Contents pane, right-click Green: Band_3.

6. What is the spectral range for Band_3?

While reviewing the image, you also notice that the Natural Color band combination is using generic band names such as Band_5 or Band_3 as part of the image layer instead of the correct band names related to color, such as Red or Green. This naming convention is making it difficult to use the imagery for analysis.

You will associate the existing band names in the layer with the correct band names, which include the appropriate spectral ranges for this sensor, so that you can more easily set the correct band combination when completing your analysis.

Step 2: Determine spectral ranges

Because you already know that the imagery is a WorldView-2 dataset, you can use technical resources to identify which bands are associated with their respective spectral ranges. In this step, you will identify the descriptive name of each of the bands.

- a In the top-right corner, click the View Help button .



If you are unable to connect to the internet, you can use the following table to complete the exercise.

- b In the Search ArcGIS Pro Help field, type **satellite sensor raster type** and press Enter.
- c Click the Satellite Sensor Raster Types result.
- d Scroll down and, on the right side of the web page, click WorldView-2.
- e Scroll down until the table displaying the spectral ranges is visible.



The following table contains the same information as the help documentation.

Tag	Band order	Wavelength (nm)	Description
Pan	1	450-800	Panchromatic
MS	1	400-450	Coastal Blue
MS	2	450-510	Blue
MS	3	510-580	Green
MS	4	585-625	Yellow
MS	5	630-690	Red
MS	6	705-745	RedEdge
MS	7	770-895	Near infrared 1
MS	8	860-1040	Near infrared 2

The help documentation includes a table that identifies the band number, the associated spectral range that is shown as wavelengths, and descriptive name. You will use this table to identify the spectral ranges in your raster dataset.

Step 3: Assign spectral ranges

Though you can conduct analysis using generic band numbers, assigning a descriptive name to each band can streamline your analysis process. In this step, you will rename each band with the descriptive name.

First, you will remove the layer from the map so that you can rename the bands.

- a** Restore ArcGIS Pro.
- b** In the Contents pane, right-click the Multispectral_16MAR23-M2AS_R3C2_P001_Bands.tif layer and choose Remove.
- c** In the Catalog pane, expand Multispectral_16MAR23-M2AS_R3C2_P001_Bands.tif, if necessary.

- d Rename Band_1 to **CoastalBlue**.

Hint: Right-click Band_1 > Rename



The band names must be typed exactly as specified in the following chart. For instance, you must type **CoastalBlue** and not Coastal blue, or **NearInfrared_1** and not Near infrared 1.

- e Using the following table, rename the remaining bands.

Band number	Band name
Band_2	Blue
Band_3	Green
Band_4	Yellow
Band_5	Red
Band_6	RedEdge
Band_7	NearInfrared_1
Band_8	NearInfrared_2

- f In the Catalog pane, right-click Multispectral_16MAR23-M2AS_R3C2_P001_Bands.tif and choose Add To Current Map.

- g** If prompted to calculate statistics, click Yes.



You have assigned descriptive names to the numbered bands, allowing you to more quickly manipulate band combinations to extract important information from the imagery.

Step 4: Examine the updated image

Next, you will explore the image.

- 7. What do you observe about the bands listed in the Contents pane and the appearance of the image in the map?**

There are other potential benefits to assigning descriptive band names.

- a** From the Raster Layer tab, in the Rendering group, click Band Combination.

- 8. Which band combinations are available?**

- b** Point to some band combinations to see which bands they use.

If all the appropriate metadata is associated with imagery, including the correct band names, ArcGIS Pro intelligently uses that information to render certain band combinations based on the sensor type. In this instance, only the names of the bands were missing. Adding this information to the image allows ArcGIS Pro to take full advantage of the WorldView-2 sensor metadata. The image is now prepared for you to use for further analysis.

- c** Save your project and exit ArcGIS Pro.
- d** Close the web browser, if necessary.

Lesson review

1. Which type of imagery collection platform will collect imagery frequently over a small collection area?
 - a. UAV
 - b. Manned aircraft
 - c. Satellite
 - d. Balloon
2. Which raster type comes from the vendor and includes commonly used raster function templates?
 - a. Raster dataset
 - b. Mosaic dataset
 - c. Raster product
 - d. Raster function

Answers to lesson 1 questions

Choose the right imagery (page 1-9)

1. How many raster datasets and raster products does the China folder contain?

Raster datasets: **12**

Raster products: **1**

2. Do you have imagery available in the China folder to conduct vegetation health analysis? Why or why not?

Yes; there is multispectral imagery in the China folder, which has the appropriate bands to conduct vegetation health analysis. Further, the raster product has processing templates set for Vegetation and Landcover analysis.

3. How many NITF files are in the Colombia folder?

There are four NITF files in the Colombia folder.

4. Give two examples of analysis that you can perform using bands in the raster dataset available in the Egypt folder.

- **The near-infrared band can be used to measure vegetation health.**
- **The shortwave infrared band can be used to measure moisture content in soil and vegetation.**

Exercise 1: Assign spectral ranges (page 1-11)

1. What is the band combination rendered for this image in your map?

Band_7 (red), Band_5 (green), Band_3 (blue)

2. Which band combinations are available?

Natural Color and Color Infrared

Answers to lesson 1 questions (continued)

3. What observation do you make about your image?

The image shows areas of potential vegetation in hues of green and brown, which were shown as red areas in the previous band combination.

4. What is the band combination rendered for this image in your map?

Band_5 (red), Band_3 (green), Band_2 (blue)

5. What is the spectral range—the minimum and maximum wavelengths in nanometers (nm)—for the Band_5 band?

The spectral range is 630 to 690 nm.

6. What is the spectral range for Band_3?

510 to 580 nm

7. What do you observe about the bands listed in the Contents pane and the appearance of the image in the map?

Now that you have assigned correct descriptive names to the numbered bands, the image displays as a natural color composite and also uses the correct band names as part of the image layer.

8. Which band combinations are available?

Natural Color, Color Infrared, Landuse, Land/Water Interface, Vegetation Analysis, and Shallow Bathymetric

2

Analyzing oblique imagery

Where are the doors and windows on a building? What are the dimensions of the doors and windows? How tall are the buildings and surrounding objects? These questions are just a few that you can answer with an oblique image. In this lesson, you will learn how to ensure that you acquire the appropriate oblique images that you need to efficiently and quickly answer intelligence questions through various visualization and analysis techniques.

Topics covered

- Visualizing oblique imagery

- Sensor information related to oblique imagery collection

- Conducting mensuration on oblique imagery

Oblique imagery

Oblique imagery is collected at significant off-nadir angles. A satellite image is generally considered oblique when it is collected at an angle greater than 15 degrees. For airborne images, this limit is not as stringent; however, it can be useful to use this angle as a metric when describing this type of imagery. These types of off-nadir viewing angles allow for a unique and valuable look at an area of interest (AOI). Oblique imagery enables you to see points of entry, measure vertical dimensions, and gain other valuable insights that otherwise might remain hidden or obscured. Both satellite and airborne (UAV or manned aircraft) platforms can collect oblique imagery.

Nadir (vertical) image collection



Image geometry:

- Vertical

Use case examples:

- Route planning
- Gridded Reference Graphic (GRG)
- Mapping

Off-nadir (oblique) image collection



Image geometry:

- Oblique

Use case examples:

- Vertical mensuration of features
- Visual image interpretation
- Area and feature orientation

Oblique imagery usage

There are distinct advantages to using off-nadir (oblique) imagery. However, sometimes it may not be the best choice to answer a particular intelligence question. Now that you understand the differences between nadir and off-nadir image collections, as well as some use case examples, consider when it might be better to use one imagery type instead of the other.

What are some advantages and disadvantages of using off-nadir (oblique) imagery when contrasted with nadir (vertical) imagery?

Coordinate systems for image analysis

There are two coordinate systems for viewing imagery in ArcGIS Pro. A map coordinate system (MCS) is the traditional viewing option that supports working with vertical imagery. An image coordinate system (ICS) supports working with oblique imagery. You can switch from the standard MCS to ICS through the perspective mode.

Map coordinate system



Image coordinate system



(Data source: Maxar [Vantor])

Image metadata

When selecting oblique imagery to use for analysis, you can ensure that you are choosing the appropriate image by examining certain fields in the metadata. These fields provide information such as the obliquity of the image (an angular description related to off-nadir collection), the collection angle (the compass direction of the satellite in relation to the center of the image), and sensor geometry. Also, sun azimuth and sun elevation information is required if measuring feature height using shadows.

When you view an image in an ICS by engaging the perspective mode, a heads-up display (HUD) appears in the map view. The HUD exhibits some of the metadata fields, such as the acquisition date and the obliquity. Other information, such as the collection angle or cloud cover, is only visible when you open and view the full metadata.

Metadata field	Display units	Impact to analysis
Obliquity angle*	Degrees ranging from 0 degrees to 90 degrees, with 0 being nadir and 90 being a completely horizontal collection angle	Higher degrees of off-nadir collection angles enable increased visualization of building faces
Collection angle**	Degrees ranging from 0 degrees to 360 degrees as a compass bearing /heading	Dictates which face of a building will be visible (for example, a 315-degree collection angle will show the southeast aspect of features)
Acquisition date and time	Coordinated Universal Time (UTC) timestamp	How current is the image? Will the image show desired features or activities based on the collection time?
Cloud cover	Percentage from 0 percent to 100 percent	Cloud cover may obscure AOI

*Collection obliquity ranges will vary between platforms. **The displayed collection angle can vary between platforms. Sometimes it is a relative look angle while other times it is the position of the satellite relative to the center of the image collection.

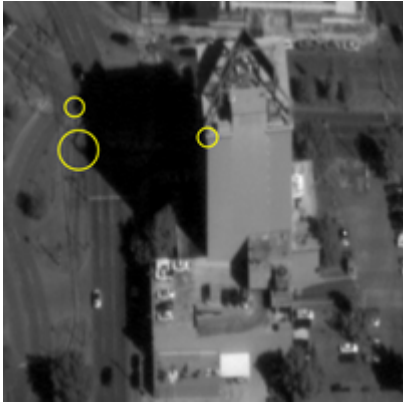
Mensuration techniques

Image mensuration can seem like a simple task, but there are many considerations and techniques to learn to ensure that you are obtaining accurate measurements. The following table lists a few of the commonly encountered scenarios when conducting mensuration.

Mensuration techniques (continued)

Example	Cause for inaccuracy	Technique to improve accuracy
	Objects along the bottoms of buildings or other features, like sidewalks, ramps, or steps, can skew measurements.	Ensure that you are measuring from the base of the building or feature and not any protruding features.
	Objects on the roof can cast shadows that would cause incorrect measurements if used for calculations.	Ensure that you are selecting features on the building and corresponding shadows on the ground.

Mensuration techniques (continued)

Example	Cause for inaccuracy	Technique to improve accuracy
	Not using corresponding object-shadow points makes it difficult to obtain accurate measurements.	Ensure that you use clearly defined, unobscured points for measurements.

(Data source: Maxar [Vantor])

Exercise 2

Analyze oblique imagery



This scenario is completely fictitious in nature and should not be viewed as a representation of an actual prior operation.

Imagine that you are a geospatial analyst working for the Drug Enforcement Agency (DEA) in New Orleans, Louisiana. Your primary focus is illegal activity at the Port of New Orleans.

Recent reporting indicated that a ship carrying illicit materials will dock at the Port of New Orleans Napoleon Container Terminal tomorrow night. DEA leadership has decided to conduct a search-and-seizure operation of the warehouse next to where the ship will be docked. This operation will take place in the early morning after the ship has docked and the cargo has been off-loaded to the warehouse for loading onto other vehicles for shipment out of the area.

Your task is to conduct analysis in support of mission planning. You have obtained oblique imagery of the Port of New Orleans and will examine it to determine whether it meets your needs. You will then identify, label, and mensurate tactically relevant information.

In this exercise, you will perform the following tasks:

- Examine oblique imagery.
- Conduct image mensuration.

Step 1: Examine imagery

You have obtained oblique imagery of the Port of New Orleans. Before conducting analysis, you will explore the image and determine whether it will meet your needs.

- a Start ArcGIS Pro.
- b Click Open Another Project.
- c Browse to **C:\EsriTraining\IMAD\Projects\New Orleans** and open the New Orleans project.



If you are working in a closed environment without internet access, from the Catalog pane, expand Maps and open Map_Disconnected.

- d From the Map tab, in the Navigate group, click Bookmarks and choose Warehouse to zoom to this bookmarked location.



- e Pan and zoom to examine various locations in the port facility.

1. What are your general impressions of features in the image?

- f** Consider the spatial resolution of the image to determine whether it will meet your needs.

2. Is the spatial resolution high enough? Why or why not?

The spatial resolution is high enough that you can discern small details in the image. Sufficient resolution will enable you to identify and more accurately measure features of interest.

- g** Zoom to the Warehouse bookmark again.

- h** In the Contents pane, open the Layer Properties for the image layer.

Hint: Right-click the layer and choose Properties.

- i** In the Layer Properties window, click the Source tab and expand Raster Metadata.

3. What is the obliquity of the image?

4. Is there metadata which will enable you to mensurate feature height from shadows?

- j** Close the Layer Properties pane.

You will now view the image in Image Coordinate Space (ICS).

- k** In the Contents pane, click the List By Perspective Imagery button .

- l In the Focusable Images group, to the left of the Panchromatic_18NOV15 image name, click the Set As Focus Image button .
- m From the Raster Layer tab, in the Rotation group, click the Rotation Type down arrow and choose Up Is Up.



Your image is now in perspective mode, which means that the image is focused (projected) into an ICS based on the geometry and collection parameters from the sensor and stored in the image metadata. When the map view display is changed to perspective mode, a heads-up display (HUD) window appears in the upper right of the map that contains essential metadata for the perspective image.

- n In the upper right of the map, point to the HUD window.

5. When was the image collected?

- o Click the up arrow  to minimize the HUD window.

Based on your examination of the image and metadata, you have determined that it will meet the needs of your analysis.

Step 2: Annotate features in the imagery

In this step, you will add annotation to the imagery to provide additional information to DEA operations.

- a From the Insert tab, in the Layer Templates group, click the More button .
- b From the list of layer templates, click Bright Map Notes.

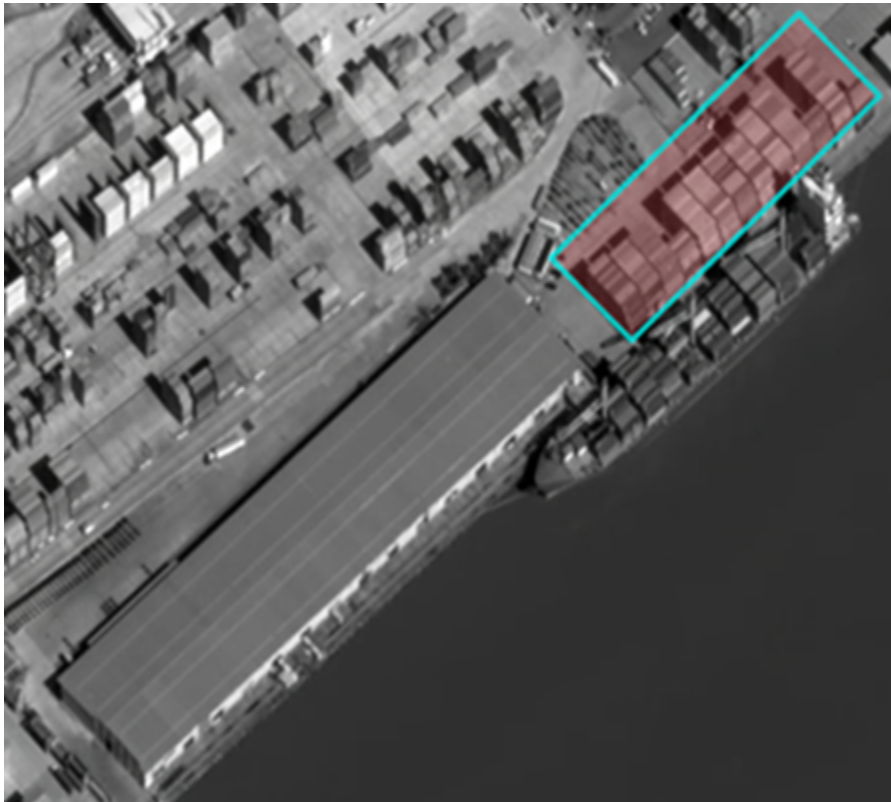
A new layer group named Bright Map Notes is added to the Contents pane. You will create features in this new layer.

- c From the Edit tab, in the Features group, click Create.

The Create Features pane opens with feature templates for line, point, and polygon map notes. You will first create a polygon feature to represent the on-dock container yard adjacent to the warehouse and the ship. This is where the cargo will be offloaded prior to being stored in the warehouse

- d In the Create Features pane, scroll down and, under Bright Map Notes: Bright - Polygon Notes, click one of the Polygon templates.

- e On your own, in the map, digitize the on-dock container yard, as shown in the following image.



You can use the Explore tool to zoom in, if necessary.

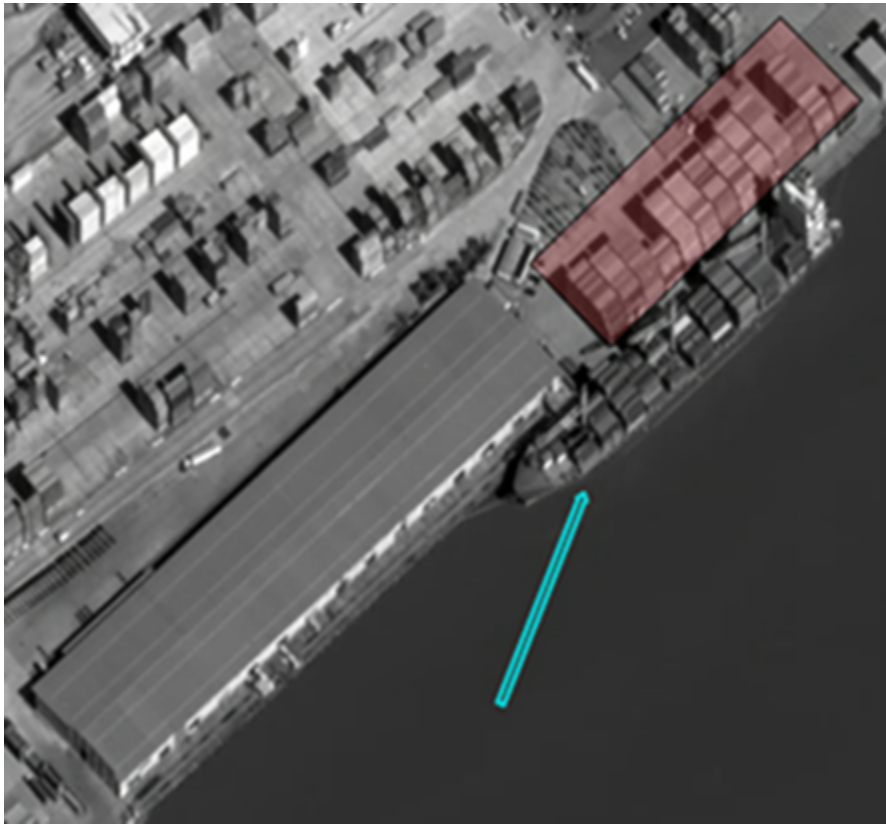
Hint: Double-click to end the sketch.

Next, you will add an arrow to point to the location of the container ship.

- f In the Create Features pane, under Bright Map Notes: Bright - Line Notes, click one of the Arrow templates.

When adding the arrow, you will first add the vertex for the tail end of the arrow and then add the vertex for the point.

- g Add an arrow pointing to the container ship.



Finally, you will add a point feature for the Entry Control Point (ECP). You will use the Locate tool to search for the ECP by its MGRS coordinate.

- h From the Map tab, in the Inquiry group, click Locate.

The Locate pane opens.

- i In the Locate pane, in the Search field, type **15RYP 79765 12951** and press Enter.

The map zooms to the MGRS coordinate that you entered.

- j Zoom out until you can see details in the image surrounding the point that was added.

In the Locate pane, one result is listed. You will add this point to your Bright Map Notes layer.

- k In the Locate pane, right-click the result and choose Add To Feature Class.

- l In the Add To Feature Class dialog box, expand Bright Map Notes : Bright - Point Notes to see the templates.

- m** Click one of the point templates, and then click OK.

You have finished adding features and will now save your edits.

- n** From the Edit tab, in the Manage Edits group, click Save.
- o** In the Save Edits window, click Yes to save all edits.
- p** Close the Locate pane to remove the previous locations.
- q** In the Edit tab and the Selection pane, click Clear to clear any selections.
- r** In the Contents pane, right-click Bright Map Notes and choose Zoom To Layer.

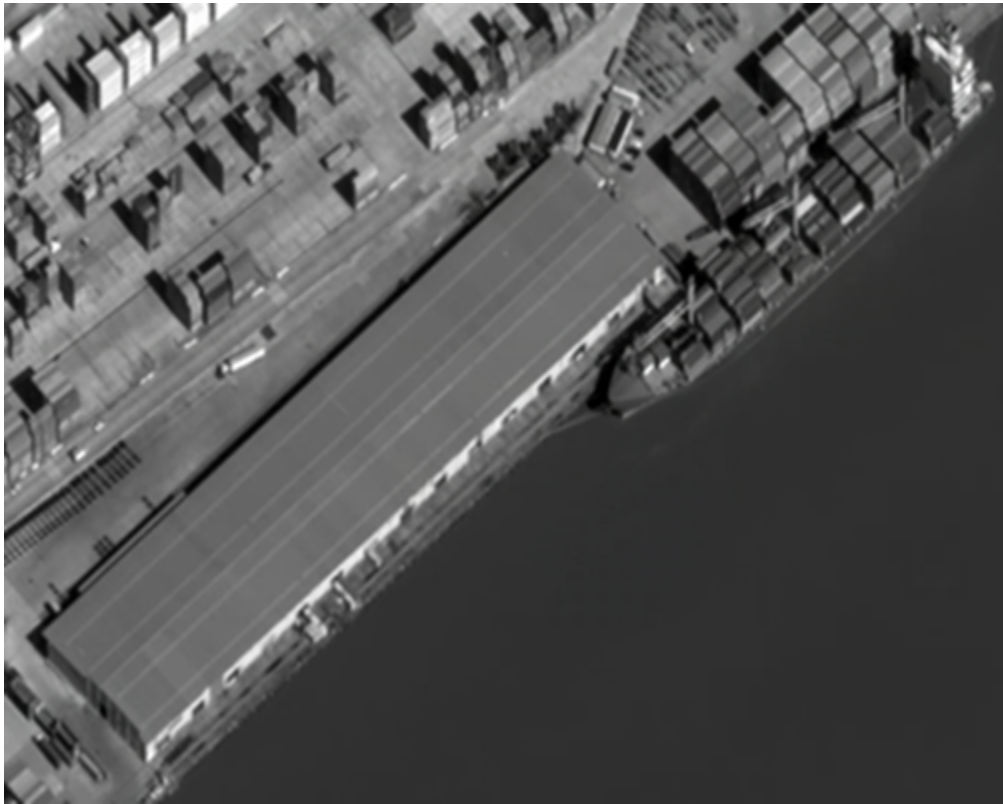
You will see all the map notes that you have added to highlight features in the image.

Step 3: Mensurate features in the imagery

In this step, you will measure features in your image.

- a** In the Contents pane, turn off the Bright Map Notes group layer.
- b** Make sure that the Panchromatic layer is displayed in an ICS.

- c Pan and zoom in to the warehouse next to the container ship.



- d Using the Mensuration tools, measure the following dimensions:

- Warehouse doors
- Building height
- Building length and width

Use your best judgment for which tool is appropriate for which measurement. Some tools require you to double-click to finish a measurement.



While measuring features, you can press the C key to enable the pan and zoom feature in your map.

While viewing an oblique image in perspective mode, you have used different mensuration tools to measure vertical and horizontal features of the warehouse.

Step 4: Set mensuration options

As you mensurate features, the Mensuration Results pane opens and displays information about the measurements. You will return to the Mensuration Results pane, but first, you will configure the units of measurement.

- a** In the Mensuration Results pane, near the upper-right corner, click the Mensuration Options button .

Mensuration Options

Units

Measurement Type	Unit
Distance	Meter
Angle	Decimal Degree
Area	Square Meter
Volume	Cubic Meters

Level of Precision

4

Symbols

Measurement Type	Symbol	Color
Point		
Distance		
Area		
Volume		
Text		

Elevation

Volume

Base Surface

Interpolate

☐ Constrain direction of cursor movement for height measurement tools

[Learn more about mensuration options](#)

OK

Cancel

In the Mensuration Options pane, you can set various parameters, such as measurement units, symbols, and colors. You can also reference an elevation source to improve the quality of your mensuration.

Mensuration tools can display results in different units of measurement. Because you are working in the United States, feet is the most appropriate unit of measurement.

- b** Under Units, set Distance to Feet.
- c** Change the Level Of Precision to **0**.
- d** Click OK.

You have changed the mensuration options so that your measurements will be shown in feet.

Step 5: Edit mensuration descriptions

When you measure features using the Mensuration tools, the results are saved as a feature class in a feature dataset. You will now edit the description of each measurement to use as a label when displaying the features.

- a** In the Mensuration Results pane, select the first measurement in your list.

The fields at the bottom of the Mensuration Results pane reflect the attributes for the selected measurement.

- b** Under Description, type the measured value from the Distance or Height field.

Distance : 1000 Feet

Description

1000 Feet

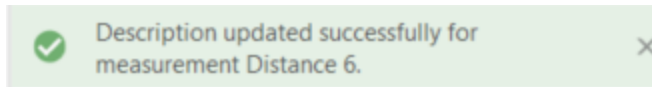
Property	Value
Sensor Name	WorldView-3
Sensor Model	RPC ICHIP
Time of measurement	3/9/2026 9:05:56 PM
Distance	1000 Feet
Sun Azimuth	262 Degrees
Image Coordinates (Start Poi	Line : 11892, Sample : 8938
Image Coordinates (End Poir	Line : 12075, Sample : 7938



Your value may be different depending on the measurement at the top of your list.



Pause briefly after each entry for ArcGIS Pro to update the description. At the top of the Mensuration Results pane, you will see a notification similar to the following graphic after each description has been successfully updated.



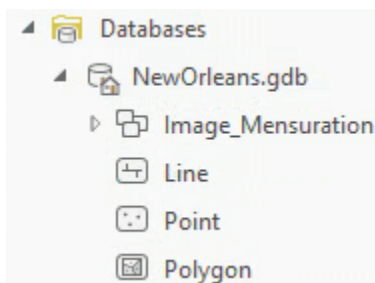
- c On your own, fill in the Description section for your other measurements.
- d After you are finished, close the Mensuration Results pane.

You have edited the description of each measurement.

Step 6: Display the measurements feature class

Now that you have updated the description for each measurement, you will adjust the labels for the line features.

- a In the Catalog pane, expand Databases, expand NewOrleans.gdb, and then expand Image_Mensuration.



If you do not see the Image_Mensuration feature dataset, right-click NewOrleans.gdb and choose Refresh.

- b Add the Line feature class to your map.
- c In the Contents pane, right-click Line and choose Label to turn on labeling.

-  Save your project and exit ArcGIS Pro.

Lesson review

1. When measuring oblique imagery, you should take measurements from clearly defined and corresponding object-shadow points to ensure the accuracy of the measurements.
 - a. True
 - b. False

2. What are MCS and ICS, and what are they used for?
-
-
-

3. Which metadata field contains information related to which face of a building that you will see when analyzing oblique imagery?
 - a. Obliquity
 - b. Cloud cover
 - c. Collection angle
 - d. Acquisition date and time

Answers to lesson 2 questions

Oblique imagery usage (page 2-3)

What are some advantages and disadvantages of using off-nadir (oblique) imagery when contrasted with nadir (vertical) imagery?

Possible responses include the following advantages and disadvantages:

Advantages:

- Easily compare heights of features against each other (for example, Building A is higher than Building B).
- Potentially see doors or windows (for example, aircraft hangar door openings and sizes).
- Potentially see under vertical obstructions (for example, temporary aircraft covers on a tarmac).
- See openings to underground facilities.

Disadvantages:

- Depending on the inclination and viewpoint of off-nadir angle, some features might be obscured.
- Can only observe one angle, or side, of a ground feature (for example, southeast face of a building).
- If the angle of observation (collection angle) is from a direction opposite to your AOI, it is of no use.
- Similar to vertical collections, shadows can obscure areas or targets of interest, but because collection times vary with oblique collections, the chance of elongated shadows increases.

Answers to lesson 2 questions (continued)

Exercise 2: Analyze oblique imagery (page 2-9)

1. What are your general impressions of features in the image?

Answers will vary but can include the following impressions:

- There is mild distortion, especially in features like the railway cars.
- Depending on where a feature is located in the image, some faces of buildings are less visible.

2. Is the spatial resolution high enough? Why or why not?

Yes; you are able to discern small details like vehicles, building entrances and exits, light posts, and shipping containers.

3. What is the obliquity of the image?

40.67 degrees

4. Is there metadata which will enable you to mensurate feature height from shadows?

Yes; the Sun Azimuth and Sun Elevation metadata provides the required sun angle information to mensurate feature height from shadows.

5. When was the image collected?

November 15, 2018, at 17:18:16 UTC

Using imagery from two different dates over the same area to detect and identify change helps decision makers assess combat effectiveness. Change detection can be difficult without the proper data and perspective regarding your analytical results. Sometimes, you can measure and quantify change for battlefield commanders and other decision makers, but operational constraints often limit that level of analysis. In most military environments, change detection is a tool used for tipping and cueing of an area as a step for further analysis. Different change detection workflows have been developed by analysts and scientists over time, and all have their own merits. While no single approach is recommended in all cases, this lesson teaches you several ways to calculate change using raster functions for further analysis.

Topics covered

 Raster functions Preprocessing imagery for analysis Change detection

Operational change detection

Every operational environment, examined at every level of warfare—whether strategic, operational, or tactical—experiences continual change. As an analyst, you may be called upon to observe, evaluate, and describe this change. Ultimately, you will need to provide your assessments to commanders and decision makers. Through various situations, imagery becomes a valuable tool that you can use to show change in your area of responsibility.

What are some examples of when you might use imagery to observe change?

How can evaluating change factor into answering intelligence questions?

Raster functions for change detection

You have several capabilities at your disposal that enable you to identify and, in some cases, quantify change. One of the easiest methods for identifying change is to use raster functions. Raster functions are operations that apply processing directly to the pixels of imagery and raster datasets as they are displayed in your map. As a result, only visible pixels are processed at any one time, with the output displayed in a temporary layer. The new layer output is displayed in the map based on the parameters specified in the raster function. Because no permanent datasets are created using raster functions and the original raster data is not affected, processes are quickly applied for immediate evaluation and analysis. In an operational environment, where timeliness is essential, the use of raster functions can be advantageous, providing quick deployment of results.

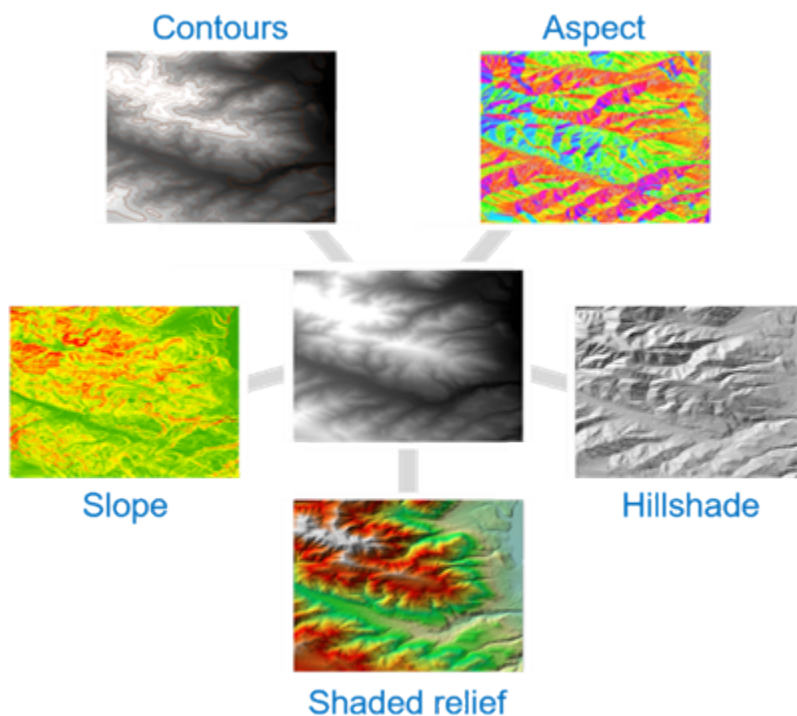


Figure 3.1. A new layer is created with a raster function from a single source file, in this case an elevation raster. Clockwise from the upper left: output contours, aspect, hillshade, shaded relief, and slope layers. (Data source: U.S. Geological Survey, U.S. Department of Agriculture, National Oceanic and Atmospheric Administration)

Common raster functions used in the defense industry

There are many types of raster functions available in ArcGIS Pro for different uses, but the most common types for working with remotely sensed imagery include functions for radiometric calibration, geometric correction, data management, visualization, and analysis. The following table contains information on common raster functions used in image analysis.

Some raster functions are applicable to only a specific type of imagery or raster. For instance, a normalized difference vegetation index (NDVI) requires a multispectral image (MSI) with a red band and near infrared (NIR) band, otherwise it will not work properly. Similarly, the Pansharpen raster function can only be used with two corresponding images, multispectral and panchromatic imagery, of the same area and ideally collected by the same sensor. It is important to understand not only what a raster function does but also what is required of the input imagery in order for the function to run properly.

Function name	Description
NDVI	Calculates the NDVI values using the red and NIR bands.
Tasseled Cap Transformation	Provides standardized detection of the built environment, soil, and vegetation by measuring levels of brightness, vegetation, and wetness.
Pansharpen	Enhances the spatial resolution of a multiband image by fusing it with a higher-resolution panchromatic image.
Apparent Reflectance	Adjusts image brightness values based on sun elevation, acquisition date, and the gain and bias settings for each band. Calibration variables are supplied in the metadata by the vendor.
Geometric	Orthorectifies imagery by incorporating an elevation model.
Clip	Clips a raster using a rectangular shape according to the extents defined or clips a raster to the shape of an input polygon feature class. The shape defining the clip can clip out the extent of the raster or an area within the raster.
Composite Bands	Combines multiple rasters into one multiband raster.

Common raster functions used in the defense industry (continued)

Function name	Description
Extract Bands	Reorders or extracts bands from a raster.
Resample	Changes the spatial resolution of a dataset.
Band Arithmetic	Calculates indices using the predefined formulas or user-defined expressions (for example, Blue Band / NIR Band = Result).
Calculator	Computes a raster from a mathematical expression (for example, Raster1 – Raster2 = Result) based on the entire raster dataset.
Remap	Allows you to group pixel values together and assign the group a new value.

Other raster functions include those for working with elevation rasters, more specific mathematical functions besides simple arithmetic operations, or hydrology functions. Some raster functions are only available with a Spatial Analyst or Image Analyst license.

1. Which raster function can you use to help enhance the spatial resolution of a multispectral image?

2. Which functions would potentially help defense analysts with computing a change detection?

Common raster functions used in the defense industry (continued)

3. Which raster function can you use to take individual rasters and create a single multiband raster?

4. What differentiates the Geometric raster function from the Resample raster function?



ArcGIS Pro Help: List of raster functions

Change detection

Using images from two different time periods to detect and extract change is a powerful analytical tool in an operational environment. There are many valid methods to perform change detection. Often, it is an iterative process of trial and error depending on many factors. After you determine whether change occurred, you can potentially determine the magnitude of the change, as well as the result of the change (from and to). This type of analytical assessment is especially important for workflows such as battle damage assessment (BDA) or order of battle (OB) changes.

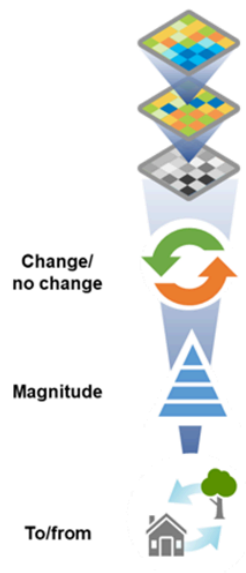


Figure 3.2. You can use imagery from two dates to compare and understand different types of change across a battlespace. You can describe whether change occurs, in some cases the amount or magnitude, and finally the type of change in an area.

Sensor impacts on change detection

For rasters to be used successfully in change detection, the change observed should be actual change on the ground rather than false change due to sensor or environmental factors. Environmental conditions can be challenging to correct, but many sensor conditions can be mitigated with ArcGIS Pro.

Preprocessing of imagery is an essential step when performing any type of image analysis but is critical when performing change detection. Raster functions can preprocess the rasters before they are used in change detection to ensure that any change measured is actual change and not merely anomalies between the two images. Preprocessing imagery to account for radiometric variance is especially important for satellite imagery. Satellite-based sensors collect all reflected energy through the atmosphere, which is in a state of constant flux. Calibrating images to account for various sensor or environmental factors ensures that the observed spectral values are comparable with each other and baselined to a similar scale.

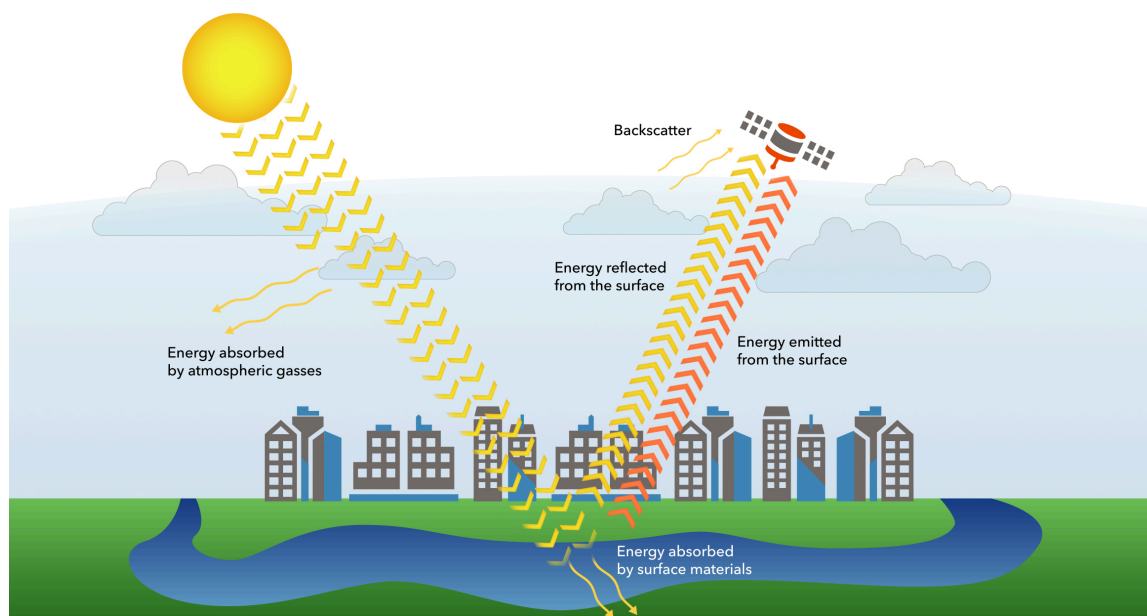


Figure 3.3. Satellite sensors collect reflected energy through a constantly changing atmosphere. Raster functions can be used to radiometrically correct images for use in different types of analysis, including change detection.

Preprocessing for image calibration

There are three main considerations to account for based on the collection parameters of a sensor. Using raster functions, you can significantly minimize potential errors in your change detection analysis.

Difference	Considerations	Mitigation Methods
Resolution	• Spatial: Same pixel size • Spectral: Same spectral bands and wavelengths • Radiometric: Confirm same bit depth (pixel type and depth) • Temporal: Similar time of year acquisition dates (for example, similar seasonal conditions)	• Resample • Extract bands • Spectral conversion
Areal	• Same geographic area • Same spatial extent	• Clip • Snap Raster environment setting
Image variance	• Similar brightness or reflectance values, a common scale	• Apparent reflectance

Preprocessing should be performed when possible and if time and operational conditions allow. There are multiple ways to perform preprocessing steps, and most can be performed using raster functions. Analysts must decide the most appropriate method to preprocess their imagery based on mission needs and requirements.

Resolution differences

To determine change with imagery, pixel values are used in the calculations. Ideally, these values will be similar when there is no change and only different in areas of change. If the imagery is collected by the same sensor, then the values returned should be relatively similar. If the same sensor is not possible, then consider using rasters with similar spatial, radiometric, and temporal resolutions. Both images should have similar spatial resolution and the same coordinate system.

Preprocessing for image calibration (continued)

Spatial differences

The key to preventing spatial registration errors is to ensure that you have good spatial extent overlap between both images. After you confirm that both rasters have these characteristics, be sure to set the Snap Raster environment prior to processing so that the pixels for each image will align properly.

Image variance

Even if the same sensor is used for each image, there can be issues with the values reported by the sensor, which can affect the raw pixel brightness values of the image.

These issues can be mitigated by converting the values of both images to apparent reflectance values, which allows them to be compared along a similar scale. Sometimes, you can compensate for this factor by performing a full atmospheric correction. This process, however, requires a complicated atmospheric model for the date and time of acquisition.

More often, you can convert the values of both images to apparent reflectance values, which also allows them to be compared on a similar scale. The Apparent Reflectance raster function calibrates imagery to an apparent reflectance value for the top of atmosphere and generates an albedo (that is, a reflectance) image. It accounts for things like radiance and bias gains of the sensor, as well as sun azimuth and sun elevation, at the time of image acquisition. Often, this type of image calibration will satisfy the preprocessing requirements necessary for change detection.

Exercise 3

Perform a change detection analysis



This scenario is completely fictitious in nature and should not be viewed as a representation of an actual prior operation.

It is September 2016. Over the past four months, the city of Aleppo, Syria, faced an intensive bombardment campaign on both rebel- and government-held locations in the city. Several buildings in the city were destroyed. You are an analyst working to survey the damage in the area. Your unit has imagery from March 2016, before the bombings in April, and new imagery collected in August 2016. There are a few locations in the city where the destruction is apparent. Your task is to find other impacted areas in the city that may not be as well known.

You will use several different workflows with both multispectral (MSI) and panchromatic (Pan) imagery to detect and identify change in an area of central Aleppo. These results will be forwarded to decision makers at non-governmental organizations (NGO) to help in relief efforts.

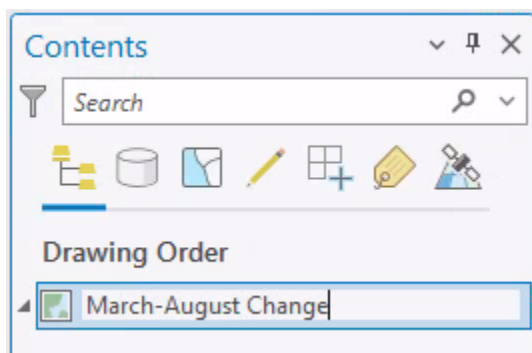
In this exercise, you will perform the following tasks:

- Prepare a map for change detection.
- Examine potential change.
- Preprocess MSI for change detection.
- Calculate and evaluate change.

Step 1: Prepare your map

While you do not need to have layers already in a map to use raster functions, it does provide contextual awareness. In this step, you will prepare a map with panchromatic images from March and August 2016.

- a Start ArcGIS Pro.
- b Under Recent Projects, locate and open the Syria project (**C:\EsriTraining\IMAD\Projects\Syria\Syria.aprx**).
- c From the Insert tab, in the Project group, click New Map to add a new map to your project.
- d In the Contents pane, rename Map to **March-August Change**.



Hint: Click the name once, and then click it again to make it editable.

- e In the Catalog pane, expand Folders and Imagery, and then expand Syria and the 2016_0803(03AUG) folder connection.

1. What type of rasters are these images?

- f** From the Catalog pane, add the Pan_03August2016.tif image into your new map.



Ensure that you add the panchromatic image and not the multispectral image.

- g** In the Catalog pane, expand the 2016_0323(23MAR) folder connection.

2. What type of rasters are these images?

- h Add the Pan_23March2016.tif image to your map.



Now that your map is prepared, you can perform a quick visual assessment of the area. You know of significant damage northwest of the Great Mosque. In the next step, you will quickly assess the damage in this area.

Step 2: Perform a visual analysis

An efficient way to evaluate change between two images is to visually compare the two. While a side-by-side comparison is a valid approach to this type of visual assessment, ArcGIS Pro allows you to swipe back and forth between multiple images. In this step, you will perform a visual interpretation of the imagery.

- a From the Map tab, in the Navigate group, click Bookmarks and choose Great Mosque.

This bookmark will zoom to a known area hard hit during the 2016 bombing campaign.

- b** In the Contents pane, ensure that the top layer, Pan_23March2016, is selected.

Because this image is a raster dataset, selecting it activates two contextual tabs: Raster Layer and Data.

- c** From the Raster Layer tab, in the Compare group, click Swipe .

- d** Move the pointer into your map.

The pointer becomes a half arrow when it is in the mapping area.

- e** Move your pointer to the top of your map until it changes to a down arrow.

- f** Click and swipe down, revealing the Pan_03 August 2016 image.



When you click to swipe, your pointer will change to a dual-side (up and down) arrow.

3. What initial observations can you make of this area?

One challenge when performing change detection, especially in mid-latitudes, is differing sun angles. Many change detection workflows recommend using images collected at the same time of year (for instance, March to March or August to August). In a military environment, this option may not always be feasible. The effects that sun angle and even the difference in collection geometries have when comparing images is often compounded with higher spatial resolution imagery.

- g** From the Map tab, zoom to the Building bookmark.
- h** On your own, swipe the top layer to evaluate this portion of the image.

4. What observation can you make about the building in this area?

5. Do these observations count as change? Why or why not?

- i** In the Contents pane, right-click Pan_23March2016 and choose Zoom To Layer.
- j** From the Map tab, in the Navigate group, click Explore to turn off Swipe.

Now that your quick visual interpretation of the imagery is complete, you will preprocess the images to prepare for change detection analysis.

Step 3: Preprocess images for analysis

In this step, you will prepare your images for change detection analysis.

- a** In the Catalog pane, expand Maps, and then right-click Multispectral Change and choose Open.

This map contains a multispectral image that was co-collected with the panchromatic imagery that you used for your simple visual analysis.



These images have been created using the same clip polygon with the Snap Raster environment setting to ensure that the correct pixels will line up with one another.

- b** From the Imagery tab, in the Analysis group, click Raster Functions.

In this type of change detection, you will be using the reflected values in the images and applying arithmetic functions to them in the form of a subtraction function. For this reason, it is important to preprocess the images to a comparable baseline. In particular, you will account for radiometric differences between the two image collection dates.

- c** In the Raster Functions pane, expand Correction and click Apparent Reflectance.

6. What operation does this raster function perform?

Hint: In the Raster Functions pane, click the General tab to read a description.

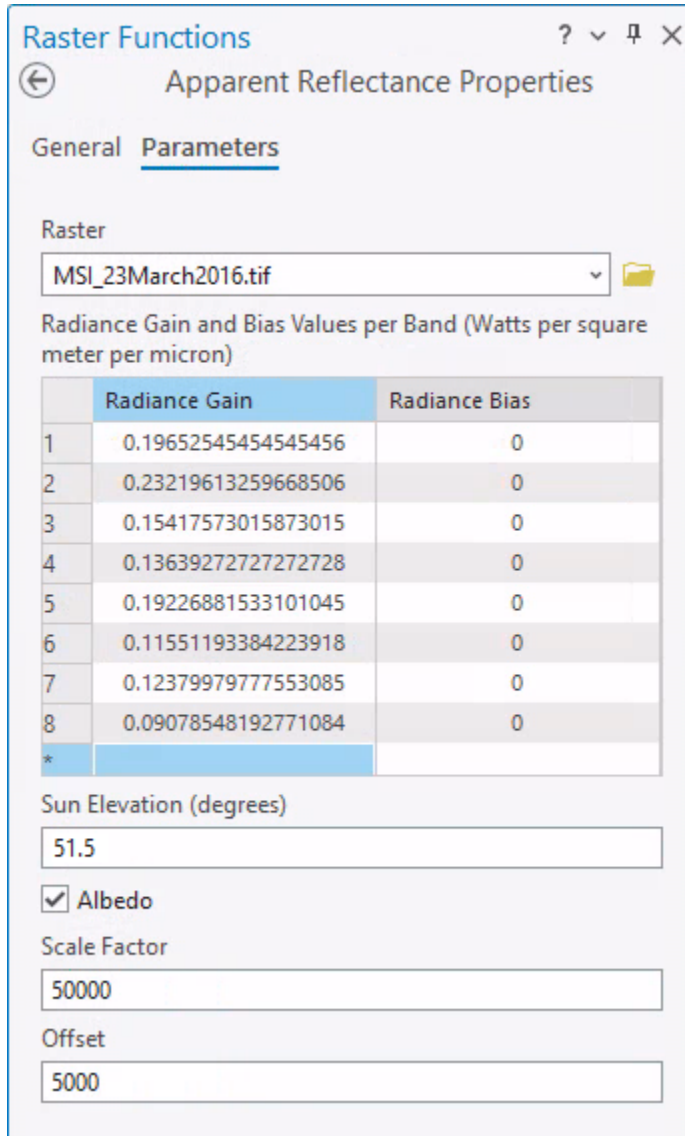
- d** In the Raster Functions pane, return to the Parameters tab, if necessary, and then for Raster, choose MSI_23March2016.

Some of the parameters are automatically entered from the image metadata, such as the sun elevation. However, because this image is a subset of a larger image collection from the vendor, the remaining information is not automatically entered into the Parameters section.

- e** In the Catalog pane, right-click the Syria folder and choose Show In File Explorer.
- f** Double-click RadianceGain-Bias (23MAR2016).txt to open it in Notepad.
- g** On your own, copy the Radiance Gain values from the text file and paste them into the Raster Functions pane using the provided table, pressing Enter after each entry.

h In the Raster Functions pane, set the following parameters:

- Sun Elevation (Degrees): **51.5**
- Albedo: Checked
- Scale Factor: **50000**
- Offset: **5000**



Raster Functions ? v 🔍 ✕

← **Apparent Reflectance Properties**

General Parameters

Raster
MSI_23March2016.tif

Radiance Gain and Bias Values per Band (Watts per square meter per micron)

	Radiance Gain	Radiance Bias
1	0.19652545454545456	0
2	0.23219613259668506	0
3	0.15417573015873015	0
4	0.13639272727272728	0
5	0.19226881533101045	0
6	0.11551193384223918	0
7	0.12379979777553085	0
8	0.09078548192771084	0
*		

Sun Elevation (degrees)
51.5

☒ Albedo

Scale Factor
50000

Offset
5000

Checking Albedo converts your images to values between zero and 1 (0.00 - 1.00). These values can be thought of as a percentage of reflectance of features, with zero being no reflectance (100 percent absorption) and 1 being total reflectance (100 percent reflectance).

i Click Create New Layer.



These images were created from a much larger set of two images and converted to TIF raster datasets specifically for this exercise. When using raster products, the values for Radiance Gain and Radiance Bias, along with Sun Elevation (Degrees), Scale Factor, and Offset, will automatically populate into the apparent reflectance raster function pane.

- j Repeat this process to convert the MSI_03 August 2016 layer to apparent reflectance values.

Hint: Use the values in the RadianceGain-Bias (03AUG2016).txt file for the parameters for the radiance gains and bias for MSI_03 August 2016.

- k In the Sun Elevation (Degrees) field, type **64.6**.
- l Check the Albedo box.
- m In the Scale Factor field, type **50000**.

- n** In the Offset field, type **5000**.

Raster Functions ? v [icon] X

← **Apparent Reflectance Properties**

General Parameters

Raster
MSI_03August2016.tif [icon]

Radiance Gain and Bias Values per Band (Watts per square meter per micron)

	Radiance Gain	Radiance Bias
1	0.196525454545456	0
2	0.328465561694291	0
3	0.21653920634920634	0
4	0.18210475935828876	0
5	0.19226881533101045	0
6	0.15427849872773536	0
7	0.12379979777553085	0
8	0.09078548192771084	0
*		

Sun Elevation (degrees)
64.6

☒ Albedo

Scale Factor
50000

Offset
5000

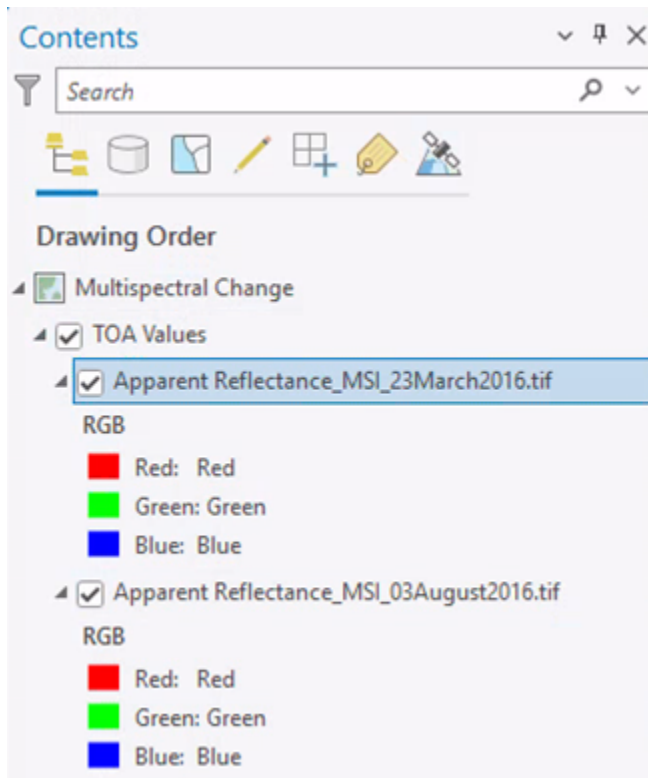
- o** Click Create New Layer.

To make layers easier to manage in your map, you can separate and group similar layers together.

- p** In the Contents pane, right-click the Multispectral Change map and choose New Group Layer.
- q** Rename New Group Layer to **TOA Values**.

- Move the two Apparent Reflectance layers into your TOA Values group layer and ensure that the March 2016 layer is on top.

Hint: Click the arrow to the left of the TOA Values group layer to expand and view the contents in the group layer.



- In the Raster Functions pane, from the Data Management group, click Extract Bands.

You will use this raster function to extract the Blue band from your MSI. Using this band may help identify changes in the urban areas. Other bands are too influenced by vegetation growth and health, as well as soil or building materials. Information in the Blue band is less sensitive to these effects of vegetation, soil moisture, or the spectral characteristics of building materials. Using the Blue band may allow for a better chance of change detection.



If other band wavelengths are available, additional methods can be evaluated. Sometimes, more advanced image processing techniques, including various indexes, can be used to help identify change. Understanding your area of responsibility (AOR), the imagery that you have for use, and band characteristics are all factors in determining more rigorous change detection workflows.

t In the Raster Functions pane, set the following parameters:

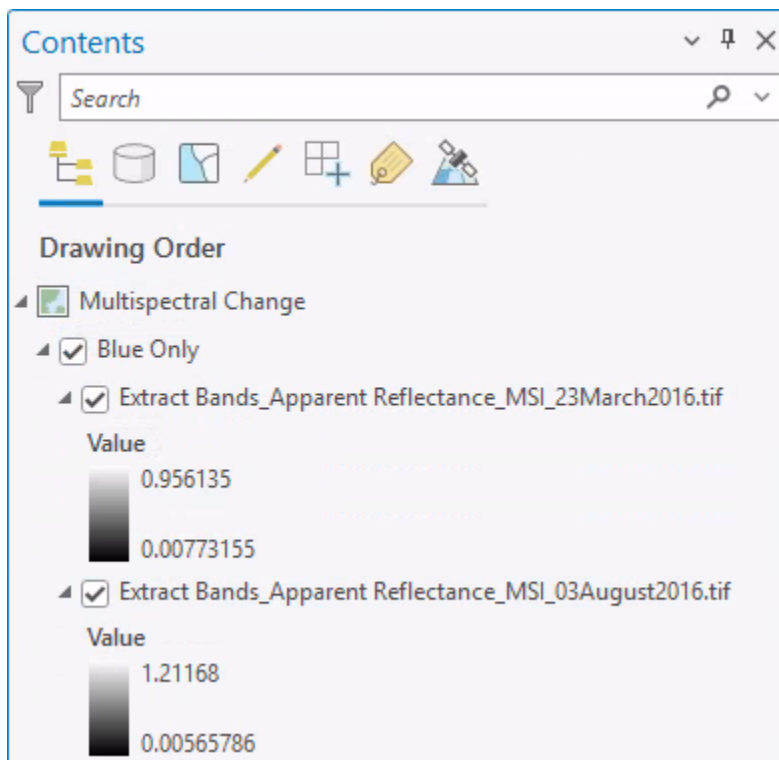
- Raster: TOA Values\Apparent Reflectance_MSI_03August2016.tif
- Method: Band Names
- Band: Blue
- Combination: **Blue**

The screenshot shows the 'Raster Functions' dialog box with the 'Extract Bands Properties' tab selected. The 'Parameters' section is active, showing the following settings:

- Raster:** Apparent Reflectance_MSI_03August2016.tif
- Method:** Band Names
- Band:** Blue
- Combination:** Blue
- Missing Band Action:** Best Match

- u** Leave the remaining default and click Create New Layer.
- v** Repeat this process to extract the Blue band from TOA Values\Apparent Reflectance_MSI_23March2016.
- w** On your own, in the Contents pane, create a new group layer and rename it **Blue Only**.
- x** Move the two Extract Bands layers into your Blue Only group layer and ensure that the March2016 layer is on top.

Hint: Click the arrow to the left of the Blue Only group layer to expand and view the contents.



y In the Contents pane, click the arrow to the left of TOA Values to collapse the group layer.

Now that your map contents are organized, you are ready to calculate change between the two images.

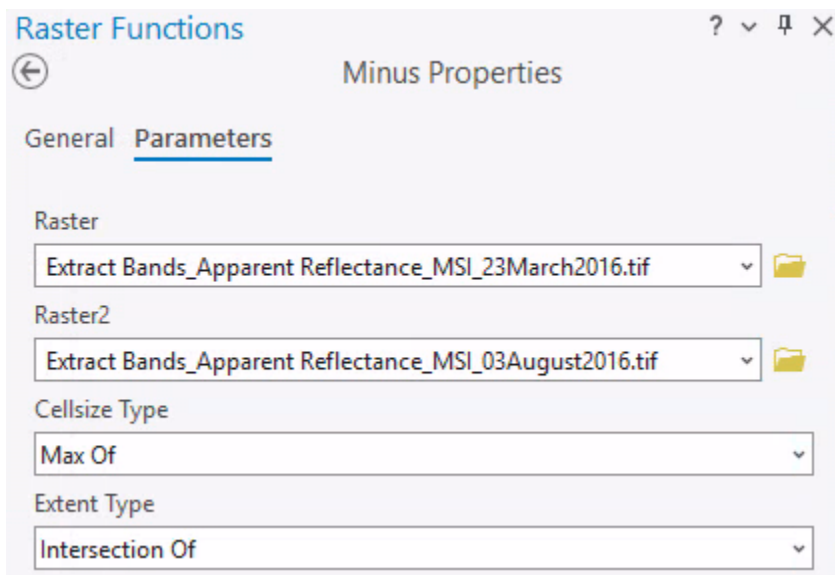
Step 4: Calculate change using raster functions

In this step, you will use raster functions to calculate change.

a In the Raster Functions pane, expand Math, and then click Minus.

b Set the following parameters:

- Raster: Blue Only\Extract Bands_Apparent Reflectance_MSI_23March2016
- Raster2: Blue Only\Extract Bands_Apparent Reflectance_MSI_03August2016



7. In your own words, what is this raster function doing with these two image layers?

- c Leave the remaining defaults and click Create New Layer.



- d Close the Raster Functions pane.
- e In the Contents pane, collapse the Blue Only group layer.
- f Turn off the Blue Only and TOA Values group layers.

In the next step, you will examine this layer to see if it is any better for tipping or cueing you to change in your area.

Step 5: Evaluate change over time

In this step, you will identify areas of change.

- a From the Map tab, zoom to the Composite Cue 1 bookmark.

8. What are your initial observations of this area?

To help with your evaluation, you will use the panchromatic image, which has a higher spatial resolution, to verify any areas of potential change. To do so, you will split and link your maps.

- b** Right-click the Multispectral Change map tab and choose New Vertical Tab Group.
- c** From the View tab, in the Link group, click the Link Views down arrow and choose Center And Scale.



- d Activate the March-August Change map by clicking its tab.
- e Ensure that the Pan_23March2016 and Pan_03August2016 layers are both turned on.
- f On your own, identify a few locations that may represent change.

There are a few areas that stand out better than others.

- g From the Map tab, zoom to the Minus Function Cue 1 bookmark.



9. Does this highlighted area denote change?



In the March-August Change map, you can turn the Pan_23 March 2016 layer on and off to see if change has occurred.

- h** From the Map tab, zoom to the Minus Function Cue 2 bookmark.



10. Do these areas highlight change?

11. Does the northernmost circled area in the preceding graphic highlight change?

- i** On your own, explore other areas in the AOR to see if the change image provides enough information for tipping and cueing.



As you pan and zoom through the AOR, you can turn the Pan_23March2016 layer on and off to help determine areas of potential change.

Often, different workflows help highlight changes. Numerical thresholds can be established that identify a range of change between values, or in values greater than x . For the examples in this exercise, you used a few simple raster functions to highlight potential change in your AOR. Despite diligence on the part of analysts, some of these changes would be missed if visual interpretation and analysis are the only tools available. Using raster functions speeds up the process and helps increase the reliability that an analyst can be cued in to areas of change.

- j** Save your project and exit ArcGIS Pro.
- k** Exit Notepad and close File Explorer.

Lesson review

1. Why is it important to preprocess your images before performing a change detection?

2. What differentiates visual change detection from change detection using a raster function?

Answers to lesson 3 questions

Common raster functions used in the defense industry (page 3-4)

1. Which raster function can you use to help enhance the spatial resolution of a multispectral image?

The Pansharpen raster function performs this operation.

2. Which functions would potentially help defense analysts with computing a change detection?

The Band Arithmetic or Calculator raster functions may be useful for change detection.

3. Which raster function can you use to take individual rasters and create a single multiband raster?

The Composite Bands raster function is appropriate for this scenario. This function can be useful if an image is separated into separate raster datasets. You can use this raster function to "build" a composite image with all the constituent bands.

4. What differentiates the Geometric raster function from the Resample raster function?

The Geometric raster function orthorectifies the imagery and corrects for terrain effects. It requires an elevation raster to process correctly. The Resample raster function changes the spatial resolution. In other words, if necessary for standardization purposes, it would change the spatial resolution of an image from 32 meters to 30 meters.

Exercise 3: Perform a change detection analysis (page 3-11)

1. What type of rasters are these images?

These images are raster datasets.

2. What type of rasters are these images?

All three of these images are raster datasets.

Answers to lesson 3 questions (continued)

3. What initial observations can you make of this area?

Answers may vary but will include the widespread destruction of buildings. Many of the buildings visible in March are obliterated and gone in August. Keen observers may notice the differences in dark areas due to shadows.

4. What observation can you make about the building in this area?

The building appears to "lean" in a different direction in the two images. The result is that you can see different sides of the building (west in March 2016 and east in August 2016). Additionally, the shadows in the March 2016 images are elongated and along a different orientation angle compared to the August image.

5. Do these observations count as change? Why or why not?

Technically, these observations would not be categorized as change if visual interpretation is the only means at your disposal. However, when raster functions compare or calculate change between two images, this could be automatically interpreted as change.

6. What operation does this raster function perform?

The Apparent Reflectance raster function converts raw imagery into Top of Atmosphere values by using sensor characteristics, the position of the sun, and the acquisition time to calibrate the sensor returns.

7. In your own words, what is this raster function doing with these two image layers?

This raster function is subtracting the reflected blue values in the August 2016 image from the reflected blue values in the March 2016 image. The result layer will show variations of change between the two.

Answers to lesson 3 questions (continued)

8. What are your initial observations of this area?

Because this image is in grayscale, it is a little easier to interpret. There are distinct bright (white) areas that immediately grab your attention; these areas may indicate change of some sort. Most of the image is gray, which may lead you to an initial assessment of overall minimal change.

9. Does this highlighted area denote change?

Yes; this building and the surrounding area have sustained severe damage in this location.

10. Do these areas highlight change?

Some of the bright spots in this area do show change, but a few do not.

11. Does the northernmost circled area in the preceding graphic highlight change?

Yes, even though it is a darker color. However, you cannot with certainty identify it as change due to bombing. In this instance, whatever caused the change in the area looks to be caused by an explosion of some type, but the damage and other contextual information is not extensive enough to make a conclusive determination.

Many remote sensing systems allow you to obtain multispectral imagery of inaccessible areas. Because this imagery contains multiple spectral bands, you can use algorithms and processes to transform this imagery into information. Examining an image can seem overwhelming with the many different band combinations possible and a large area of responsibility (AOR). To make decisions about the information contained in the imagery, you need the ability to turn the data into actionable intelligence about an area. Image classification converts imagery into thematic layers that can be used to make effective decisions in a timely manner. This lesson introduces you to image classification in ArcGIS and provides guidance for making the decisions needed when performing image classification.

Topics covered

- What is image classification?
- Image classification types and methods
- Situational classification workflows

What is image classification?

Image classification refers to the task of assigning classes to all the pixels in a remotely sensed image. These classes are part of a classification system, which is also known as a schema. By grouping data into classes with similar characteristics, analysts can modify the imagery from solely quantitative values into qualitative or thematic information. Analysts can then provide decision makers with information and answer intelligence questions about an area, not only in terms of change but also by defining what is visible in an image.

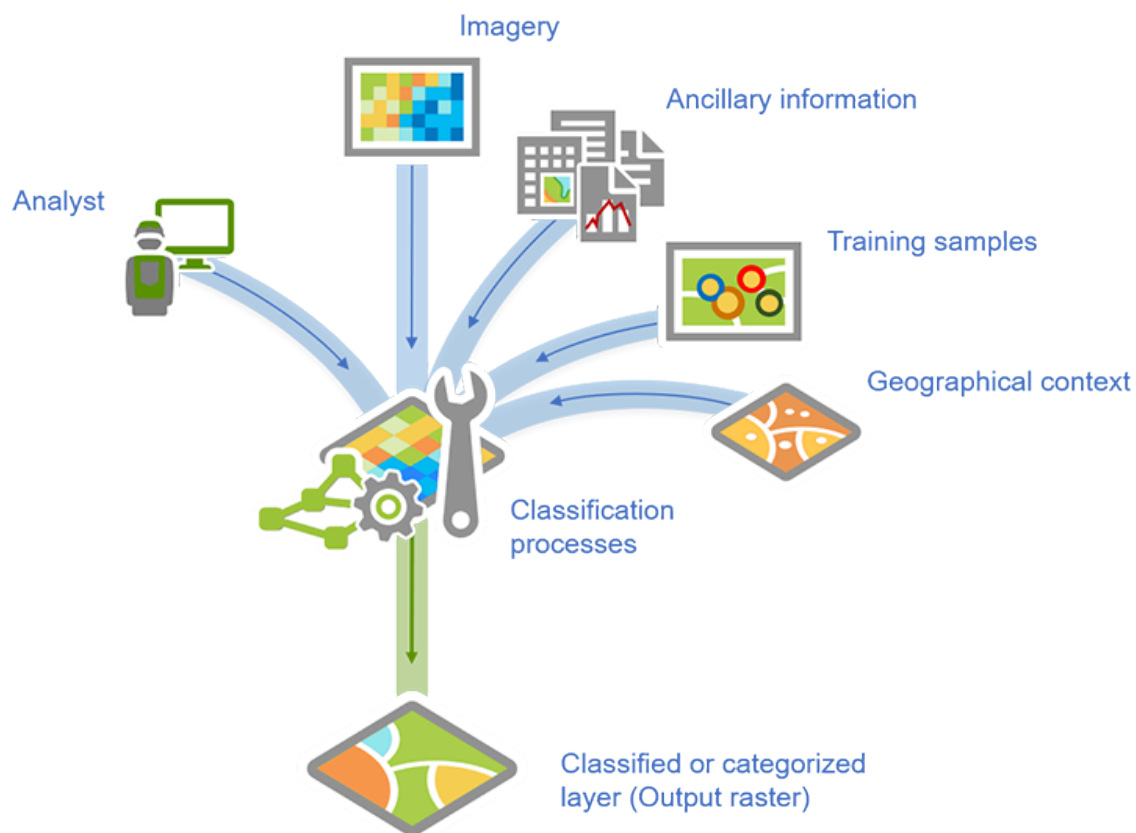


Figure 4.1. Analysts use many different types of input information when performing image classification. At its core, image classification clusters similar pixels into classes. Use of other information (for example, training samples, spectral signatures, and other contextual data) helps strengthen your results.

What is image classification? (continued)

Performing a classification requires a multispectral image (MSI), ancillary information (such as a classification schema), training samples (if available), and an understanding of the contextual geography. Sometimes, this process is called terrain categorization (TERCAT). The output raster from image classification is a thematic map.

Image classification can be used to answer many types of questions about an area, as shown in the following examples:

- Where are potential vehicle concealment and cover locations?
- What are the characteristics of the built environment?
- What is the size of the flooded area?

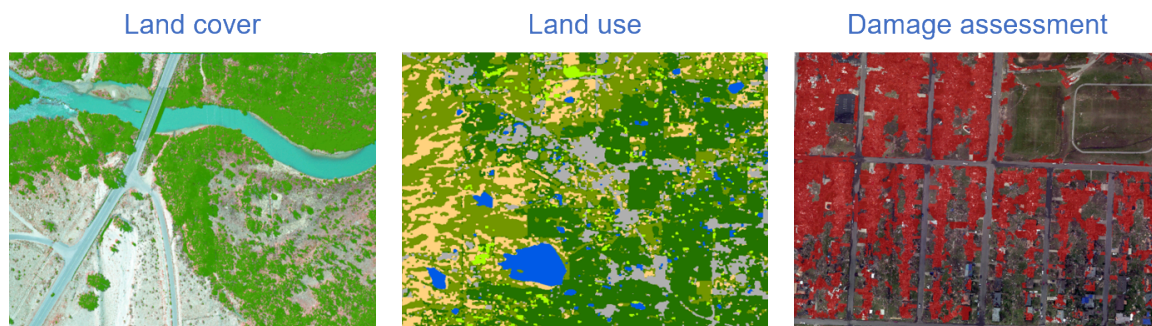
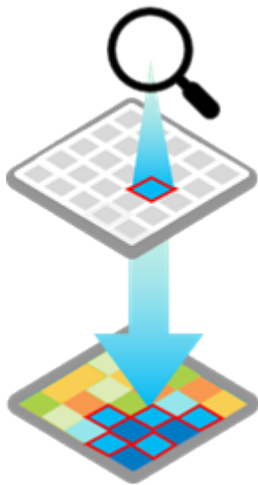


Figure 4.2. There are multiple examples of thematic output layers. These layers can be used for further analysis or as stand-alone maps.

Image classification types

There are two options for classification types: pixel-based or object-based. Both approaches have benefits and limitations. Consider the analytical situation and what ancillary information that you have access to when choosing which type to use for your analysis.

Pixel-based type



This traditional approach considers each pixel individually and does not consider any information from neighboring features. Each pixel is assigned a class independent of its spatial context. This type works well with coarse resolution raster data where the real-world features are difficult to recognize. It is also useful if you have known spectral signatures of real-world features with which you can compare your classification results. Because the spatial context is not considered with this type of classification, there are usually some image noise errors that will result in a speckled (salt-and-pepper) appearance and need to be addressed in post-processing.

Object-based type



This type uses a process called segmentation to group neighboring pixels into objects (referred to as segments) based on similar spectral and spatial characteristics. Each segment of grouped pixels is assigned a class. This type is especially useful when working with high-resolution rasters, as these segments more closely resemble real-world features than individual pixels. Object-based type image classification creates cleaner results by reducing errors caused by image noise, which can create a speckled appearance. It is also advantageous because the aggregation of pixel values into segments provides additional spectral and spatial attributes that classifiers can use. Because only three bands can be used at once, the spectral component is limited.

Image classification methods

The image classification methods available in ArcGIS Pro fall into two categories: unsupervised and supervised. Each method can be used to classify either individual pixels (pixel-based) or segments (object-based). One of the main differences between unsupervised and supervised is the level of interaction between the analyst and the computer.

Unsupervised method



Figure 4.3. The unsupervised classification method allows for the clustering of spectrally similar pixels or segments into classes. This method relies on a computer to determine the initial clusters or classes.

Unsupervised classification methods rely on a computer to determine which classes are present in an image based on the spectral characteristics and statistics of the pixels or segments. Pixels or segments are assigned to clusters based on their distribution in multidimensional attribute space. The analyst assigns the classes according to the desired classification schema after the unsupervised method is executed. Often, more than one of the initial clusters represent the desired class, so the user must combine the classes into the target classes for analysis.

- **Resolution:** High or low
- **Access:** Does not require prior knowledge or initial ground truth
- **Geographical context:** Does not require foreknowledge of the terrain or vegetation
- **Bands:** Few or many
- **Training samples:** Not required

Image classification methods (continued)

Supervised method



Figure 4.4. The supervised classification method uses input from an analyst to classify pixels or segments.

Supervised classification relies on user input initially to determine the classes within the image. The analyst creates training samples from pixels or segments that represent the target classes in the classification schema. These samples are used to train a classifier to identify all other pixels or segments that fall into one of the target classes.

- **Resolution:** Often performs better with higher spatial resolution imagery
 - **Access:** Requires ground truth (or an existing understanding of ground features)
 - **Geographical context:** Requires working knowledge of the terrain and vegetation
 - **Bands:** Performs better with more bands
 - **Training samples:** Required
1. You have a new image collection over North Korea. This imagery contains 15 multispectral bands, including shortwave infrared (SWIR) bands, with a spatial resolution of 3 meters. You have no information about features on the ground. You need to generate a thematic layer for potential drop zones. Which classification method is most appropriate to use?
-
-

Image classification methods (continued)

2. Leadership tasked your unit to help establish a new forward air base. The survey team returned from the area with detailed information, including ancillary data and reports about existing ground cover. The imagery that you have of the area has eight bands and a spatial resolution of 2 meters. Which classification method would you use to create an initial thematic layer for planning purposes?
-
-

3. You have four-band imagery, three visible bands and one near infrared (NIR) band, of a site suspected of storing chemical weapons. The site survey team cannot find any evidence of storage, current or past. However, they have observed patches of sparse vegetation and have collected these locations as training samples. What is the most appropriate method of classification to use to see if chemical contamination has occurred in this area?
-
-
-

4. As an analyst for a deploying unit, you are tasked with updating the GEOINT layers in your AOR, which contains a wide swath of mixed terrain. Because it is so large, the most efficient way to analyze the entire area is with a 30-meter MSI. The previous unit deployed near your AOR does not have any ancillary information to forward to you because they were responsible for another location in-country. What is the most appropriate method of classification to use to generate a base thematic layer for use in your maps and analysis?
-
-
-

What is deep learning?

Artificial intelligence (AI) is a broad field of technology that enables computer systems to collect, analyze, and respond to information without the need for extensive user input. One type of AI is machine learning, which uses algorithms to process data. Machine learning algorithms can be used when performing the supervised classification workflow. However, a subset of machine learning is deep learning. Through the use of neural networks, deep learning algorithms process information in a way that mimics the human brain.

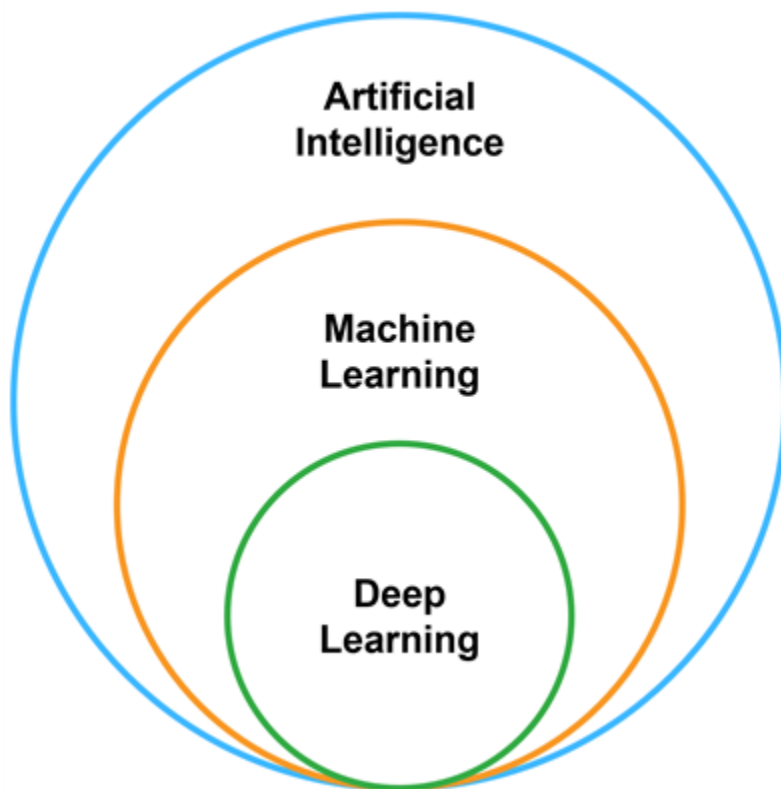


Figure 4.5. Artificial intelligence includes the subtypes of machine learning and deep learning. Deep learning is a more complex and autonomous type of machine learning.

Neural networks

A neural network is a structure of node layers, where each node analyzes and filters information before passing it to the next layer in the network. As the information is passed through the network layers, the resulting information is increasingly defined for the given analysis. Neural networks have at least three node layers: one inputs layer, one or more middle "hidden" layers,

What is deep learning? (continued)

and one outputs layer. Deep learning refers specifically to the use of a neural network that is more than three layers deep.

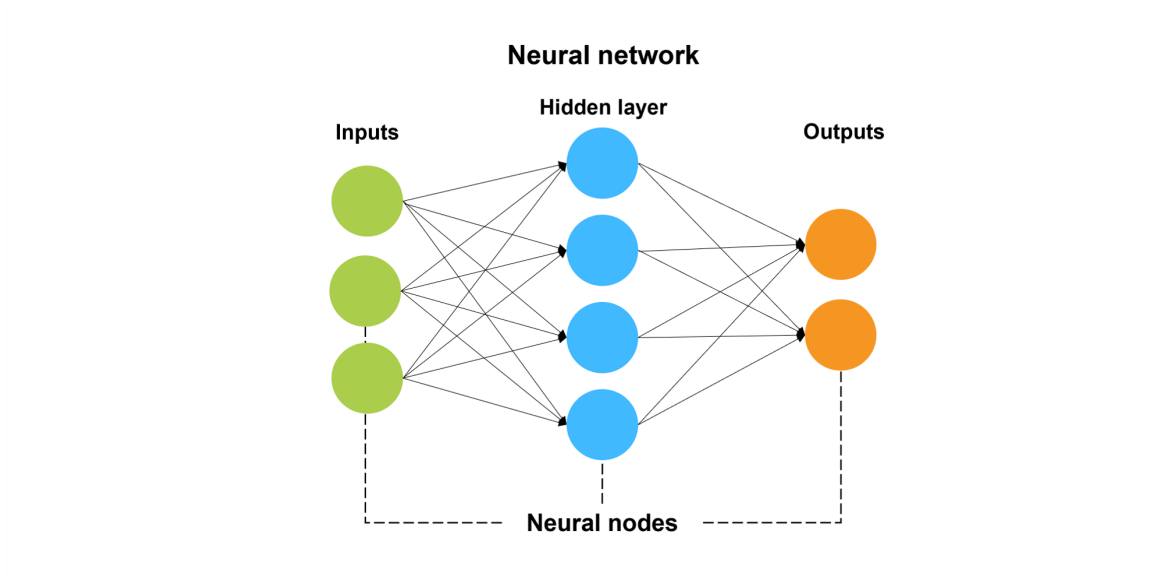


Figure 4.6. A neural network consists of layers of neural nodes that analyze information. In this example, information is passed through the network layers from left (inputs) to right (outputs).

Deep neural networks

Deep neural networks are used to train models that can be used repeatedly without the need for user input. Unlike basic machine learning, which requires manual input to prepare data and analyze the algorithm results, deep learning models, once fully trained, can consume large amounts of raw data and extract information without user input. An effectively trained deep

What is deep learning? (continued)

learning model provides access to data in ways that may not be possible with the use of more traditional, manual interactions.

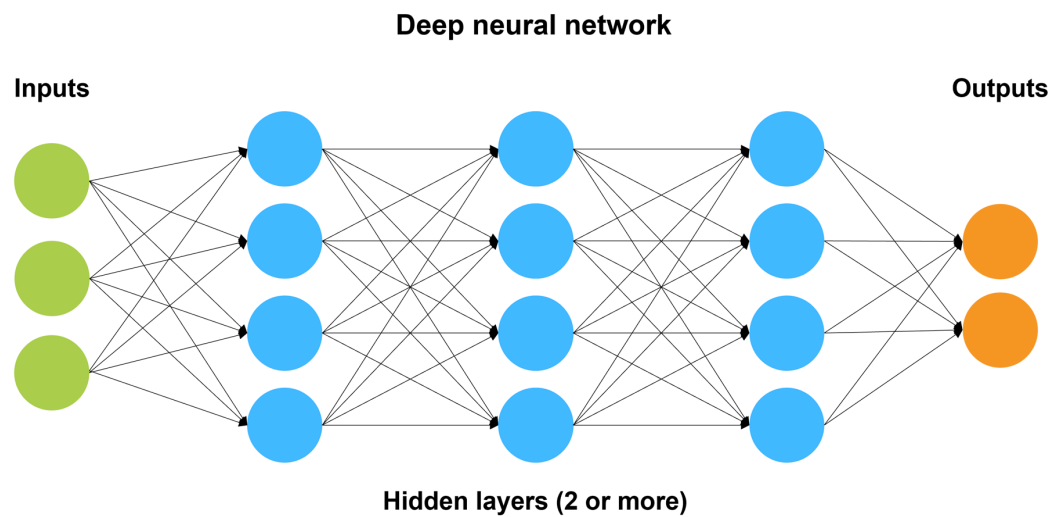


Figure 4.7. A deep neural network has multiple hidden layers.

Deep learning tasks for image analysis

Deep learning to extract information from visual inputs, such as imagery, is accomplished through specific deep learning tasks. The task that you choose will depend on your analysis objective and desired output. The following information describes image analysis deep learning tasks and provides an example of how each task can be applied. Read about the tasks, and then answer the questions in the workbook.

Image classification

Image classification involves assigning a label or class to a digital image. In this example, a digital image was captured as part of a utility field survey and labeled as a fire hydrant.



Figure 4.8. This object was labeled as a fire hydrant through image classification of the digital image.

Object detection

Object detection is the process of locating specific features in an image. This process typically involves drawing a bounding box around the features of interest. Object detection can be used to locate specific features in satellite, aerial, or drone imagery and then plot those features on a

Deep learning tasks for image analysis (continued)

map. In this example, an object detection deep learning model detected the location of trees in a neighborhood from high-resolution imagery.



Figure 4.9. Trees in this neighborhood were identified from high-resolution imagery through object detection.

Instance segmentation

Instance segmentation is a more precise object detection task in which the boundary of each object instance is drawn. For example, in the following image, instances of houses were detected with a defined outline of the building shape.



Figure 4.10. The boundaries of houses in this neighborhood were detected through instance segmentation.

Deep learning tasks for image analysis (continued)

Semantic segmentation

Semantic segmentation is a pixel-based classification task in which each pixel in an image is assigned to a class. This deep learning task can be used like traditional pixel-based image classification to create thematic rasters such as the following damage-assessment map.



Figure 4.11. This damage-assessment map is a thematic raster created through semantic segmentation. (Data source: National Oceanic and Atmospheric Administration)

Panoptic segmentation

Panoptic segmentation combines semantic segmentation and instance segmentation to classify each pixel in an image and to define instances of unique objects. For example, the following image shows that all the pixels are classified and that each unique object, such as each car, is its own unique object.



Figure 4.12. Panoptic segmentation of this street image classified each pixel and defined each unique object.

Deep learning tasks for image analysis (continued)

Image translation

Image translation is the task of translating an image from one representation or style to another, such as noise reduction or increasing resolution. For example, the following image on the left shows the original low resolution, and the image on the right shows the result of using a super-resolution model.



Figure 4.13. Image translation changed the low-resolution image on the left into the super-resolution image on the right.

Change detection

A change-detection deep learning task identifies changes in a feature of interest between two dates and generates an output that shows the changes. For example, in the following graphic, the image on the left shows a housing development as it was five years ago, the middle image

Deep learning tasks for image analysis (continued)

shows the same development today, and the image on the right shows the change in houses (in white) between the old image and the new image.



Figure 4.14. Houses built in the past five years were identified through change detection. (Data source: U.S. Geological Survey)

1. Which type of deep learning task is used to assign each pixel in an image to a class?

2. How is object detection different from instance segmentation?

Improving classification

The accuracy of analysis and interpretation depends on the quality of the imagery, various imagery characteristics, and even the available ancillary data. The detail of the classification schema and the experience of the analyst are also important. It is up to the analyst to consider all these factors and characteristics when performing an image classification.

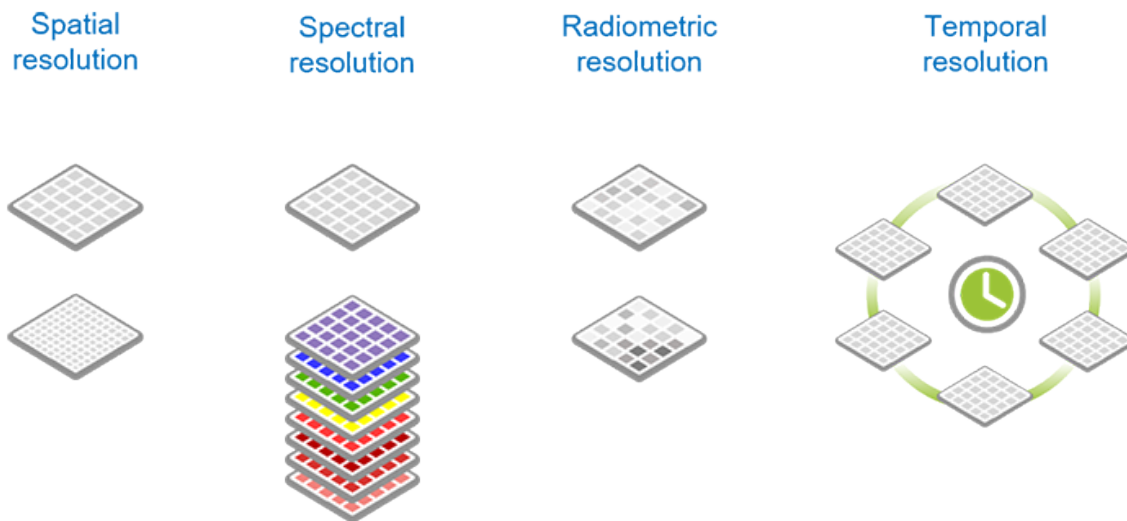


Figure 4.15. Image characteristics, including the four types of resolutions, can have a profound impact on the quality of your image classification.

Understanding the methods and types of the classification is only a first step in extracting information from imagery. Characteristics of an image are also factors that affect your end results. For instance, a higher spectral resolution may help with feature discrimination of a pixel-based classification, while a higher spatial resolution can prove to increase the accuracy of an object-based (segmented) classification. A higher radiometric resolution may provide better variation of features, if that is required, while a lower radiometric resolution may reduce confusion when creating clusters. When considering time, images collected in the spring may help distinguish tree types (coniferous and deciduous) from one another, and winter images in climate areas with little snow may help identify certain winter crops. Finally, classifying and comparing images collected six months apart may even provide unique insight and clarification of ground features.

Choosing a classification workflow

Image classification can be a powerful tool to transform imagery into information. One challenge that analysts face is determining which type and method best suit the mission set and information needed. As previously mentioned, you can apply either classification method to either type. In some instances, a deep learning methodological approach may be an appropriate choice. There is not a one-size-fits-all solution or a workflow for every situation. Each individual intelligence question or problem set is affected by many factors. However, there are some examples or use cases where one workflow may work better or be more appropriate than another. Familiarization and practice will help you decide which cases are best suited for each situation.

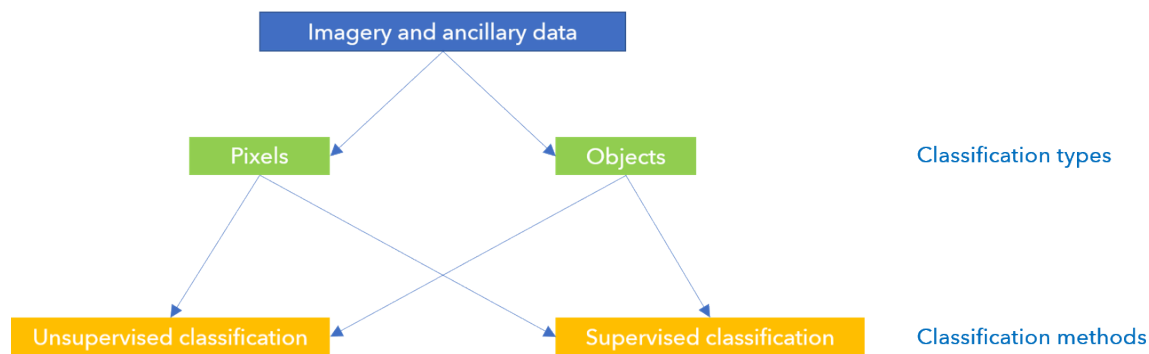


Figure 4.16. You can combine the two classification methods with the two classification types, depending on the operational scenario. Sometimes, a particular workflow will give you better, more reliable results than another.

In the following scenario, you will determine which classification type and method is the most appropriate to answer the specific intelligence problems.

Scenario 1: Illicit crop locations

Imagine that you are an analyst with an agency which sends teams to eradicate illicit crops before they can be harvested. The groups growing these crops plant them in remote and denied areas. To help identify illicit crop cultivation areas, you have several images of previously identified cultivation locations, collected multiple times during the growing cycle. You also have created a suitability model that has narrowed down potential cultivation sites. You have high confidence in your model, but it has only reduced the search area by about 40 percent.

Choosing a classification workflow (continued)

You have two types of imagery that you can use to further narrow down potential search areas. One of your collection sets contains several images that are of medium spatial resolution and medium spectral resolution (10 multispectral bands). The advantage with this imagery is that two of the MSI bands are in the SWIR portion of the spectrum. You also have an additional set of five images. This second set of imagery is of a high spatial resolution—you can easily see irregular agriculture fields—but it only has eight MSI bands. These eight MSI bands only reach into the NIR region of the electromagnetic spectrum.

You have little to no ground-truth information of the area. The eradication teams have provided locations of eradicated crop cultivation areas from last year, but you can rule out many of those locations. Finally, you have a series of spectral profiles (spectral signatures) of the plants during critical life cycle phases.

You have limited time to perform your analysis. The eradication teams will be deploying soon and need the information before departure.

1. Which classification type would be most appropriate to find the illicit crop locations?

Choosing a classification workflow (continued)

- 2. Because you are analyzing a remote area about which you have limited information, what is the most appropriate classification method to use?**

- 3. What advantage does the multiple image collection give you?**

- 4. Does having spectral signatures of the plants that you are looking for provide any other beneficial information?**

Choosing a classification workflow (continued)

Lesson review

1. How does object-based classification differ from pixel-based classification?

2. Which image classification method requires user-defined training samples to recognize specific features?

- a. Object-based
- b. Pixel-based
- c. Supervised
- d. Unsupervised

Answers to lesson 4 questions

Image classification methods (page 4-5)

1. You have a new image collection over North Korea. This imagery contains 15 multispectral bands, including shortwave infrared (SWIR) bands, with a spatial resolution of 3 meters. You have no information about features on the ground. You need to generate a thematic layer for potential drop zones. Which classification method is most appropriate to use?

Because you have no information about ground features or training samples, an unsupervised classification is recommended for this scenario.

2. Leadership tasked your unit to help establish a new forward air base. The survey team returned from the area with detailed information, including ancillary data and reports about existing ground cover. The imagery that you have of the area has eight bands and a spatial resolution of 2 meters. Which classification method would you use to create an initial thematic layer for planning purposes?

With the detailed information from the survey team, you will probably have enough ground truth and training samples to perform a supervised classification.

3. You have four-band imagery, three visible bands and one near infrared (NIR) band, of a site suspected of storing chemical weapons. The site survey team cannot find any evidence of storage, current or past. However, they have observed patches of sparse vegetation and have collected these locations as training samples. What is the most appropriate method of classification to use to see if chemical contamination has occurred in this area?

Even though this image is only four bands, the training samples collected by the survey team give you an advantage in your analysis. You can use this information to perform a supervised classification and extrapolate the results to the rest of the site.

Answers to lesson 4 questions (continued)

4. As an analyst for a deploying unit, you are tasked with updating the GEOINT layers in your AOR, which contains a wide swath of mixed terrain. Because it is so large, the most efficient way to analyze the entire area is with a 30-meter MSI. The previous unit deployed near your AOR does not have any ancillary information to forward to you because they were responsible for another location in-country. What is the most appropriate method of classification to use to generate a base thematic layer for use in your maps and analysis?

In this instance, an unsupervised classification method is a valid first approach. The relatively low spatial resolution and lack of any ancillary data, no foreknowledge of the area, and the varied terrain elements make this method a good place to start.

Deep learning tasks for image analysis (page 4-11)

1. Which type of deep learning task is used to assign each pixel in an image to a class?

Semantic segmentation

2. How is object detection different from instance segmentation?

Object detection locates the occurrence of an object in an image, typically defined with a bounding box. Instance segmentation locates the object and produces a defined outline of the object instance.

Choosing a classification workflow (page 4-17)

Scenario 1: Illicit crop locations

1. Which classification type would be most appropriate to find the illicit crop locations?

Either type is valid, but for an initial workflow process, a pixel-based approach may provide the best results with the medium spatial resolution imagery. Conversely, because you can clearly observe irregular agriculture fields in the high spatial resolution imagery, you could use an object-based approach and identify segments in the image for classification. Depending on the analysis complexity and the delivery timeline, you may decide to use one type over the other.

Answers to lesson 4 questions (continued)

2. Because you are analyzing a remote area about which you have limited information, what is the most appropriate classification method to use?

In this instance, the most appropriate method would be an unsupervised method.

However, when an initial classification is completed, you may be able to use identified clusters and use the resultant information to perform a supervised classification.

Because you have two types of imagery (medium- and high-resolution images), you can use them in tandem to verify and improve your overall classification. A further refinement of this approach could include deep learning. Once initial areas are identified, you could use those field locations as labels to train a deep learning model to help identify crops in different areas but with similar conditions. In the end, many of the workflow steps are iterative and can be revised or augmented during the actual workflow.

3. What advantage does the multiple image collection give you?

Because you have multiple images from different sensors, you can use multiple types of workflows. Additionally, the increased temporal resolution may provide you with more insight as you can observe potential growing locations change. If processing time allows, you can combine classification and change detection to improve your analysis.

4. Does having spectral signatures of the plants that you are looking for provide any other beneficial information?

Potentially, yes. After your initial classification is complete, you can correlate a spectral signature from one of your illicit crop classes or clusters with the known spectral signature. If they are similar, you can use a high-probability location for illicit crops. A further refinement of this approach could include deep learning. Once initial areas are identified, you could use those field locations as labels to train a deep learning model to help identify crops in different areas but with similar conditions. The spectral signature acts as another means of verification or quality control of your final analysis.

5

Performing unsupervised pixel-based classification

Classifying images into thematic raster data can be a powerful way to analyze and visualize complex information. Previously, you were introduced to the different types of image classification and the two image classification methods available in ArcGIS: supervised and unsupervised. During image classification in ArcGIS Pro, both methods follow a unique workflow. In this lesson, you will be introduced to the workflows associated with unsupervised pixel-based classification.

Topics covered

- Image Classification Wizard

- Unsupervised pixel-based classification

Unsupervised pixel-based classification

When performing classification, you can run individual geoprocessing tools or raster functions. You can also use the Image Classification Wizard, a guided workflow that adjusts functionality based on the chosen classification method and type, along with other initial configuration inputs.

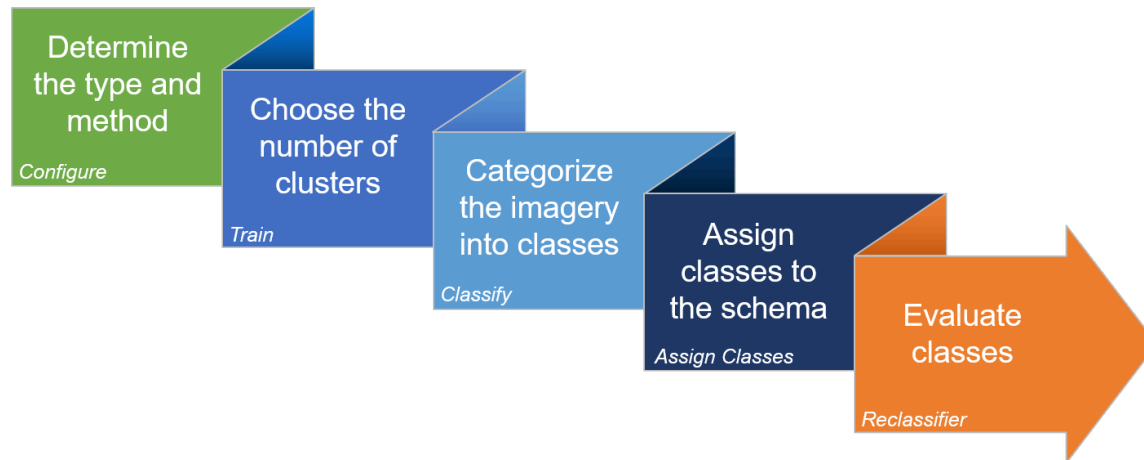


Figure 5.1. The Image Classification Wizard provides a step-by-step workflow for an unsupervised pixel-based classification.

Exercise 5

Perform an unsupervised pixel-based classification



This scenario is completely fictitious in nature and should not be viewed as a representation of an actual prior operation.

You are a geospatial analyst working on a joint task force of U.S. Southern Command (USSOUTHCOM) and local drug enforcement authorities to help eradicate illicit coca growth in the Rio Mira region in Colombia and Ecuador. You have 8-band multispectral imagery available for your analysis. Before performing this classification, you created a mosaic dataset of your imagery to better manage the four raster products as a single image. This imagery was collected in June and coincides with the second harvest of the year. Even though most sowing occurs in December and January, you hope to be able to find younger, less mature plants during the annual growing cycle.

Because of the remote nature of the area and the lack of sufficient ground truth in the form of training samples, you decide to perform an unsupervised classification using a pixel-based type of workflow. After your classification is complete, your hope is that you can use the identified potential grow locations—along with other historical fields and harvest sites—to create a thematic layer for further analysis and evaluation.

In this exercise, you will perform the following task:

- Create an unsupervised pixel-based classification.

Step 1: Configure your classification workflow

In this step, you will configure the Image Classification Wizard to perform an unsupervised pixel-based classification on your mosaic dataset of potential grow sites.

- a Start ArcGIS Pro, and then click Open Another Project.
- b Browse to **C:\EsriTraining\IMAD\Projects\Colombia** and open the Colombia project.

1. In the Illicit Crops map, what type of layer is the Region_RioMira dataset?

Hint: In the Catalog pane, from Folders, expand the second Colombia folder and the CropDetection geodatabase to see the source dataset.

- c On your own, use the Explore tool to examine various areas in the imagery.
- d After you have viewed different portions of the region, in the Contents pane, right-click Region_RioMira and choose Zoom To Layer.
- e From the Imagery tab, in the Image Classification group, click Classification Wizard.
- f In the Image Classification Wizard pane, for the Configure step, set the following parameters:
 - For Classification Method, choose Unsupervised.
 - For Classification Type, choose Pixel Based.
 - For Classification Schema, click the Classification Schema button  down arrow and choose Use Default Schema, which will populate the field as NLCD2011.

- For Output Location, browse to `..\EsriTraining\IMAD\Imagery\Colombia\CropDetection.gdb`.
- Under Optional, for Reference Dataset, leave this field blank.

Image Classification Wizard

Configure

Classification Method
Unsupervised

Classification Type
Pixel based

Classification Schema
NLCD2011

Output Location
C:\EsriTraining\IMAD\Imagery\Colombia\CropDetection.gdb

Optional

Reference Dataset

9 Click Next.

You have completed the first step in the Image Classification Wizard. Next, you will train the classifier.

Step 2: Train the classifier

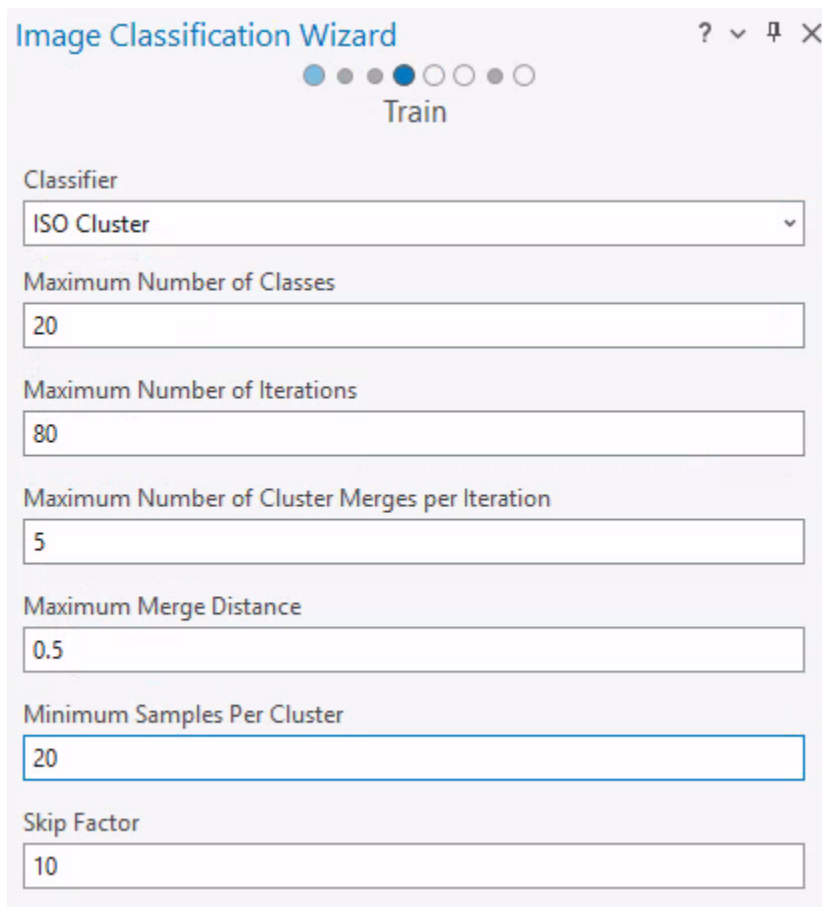
In this step, you will train the classifier to group, or cluster, similar pixels in your image.

2. In the Train step, what are the Classifier options available to you?

The ISO Cluster tool organizes spectrally similar, natural groupings of pixels or segments into a user-specified number of clusters. It performs this action in an iterative fashion. The analyst also determines the number of iterations.

a For the Train step, set or confirm the following parameters:

- Maximum Number Of Classes: **20**
- Maximum Number Of Iterations: **80**
- Maximum Number Of Cluster Merges Per Iteration: 5
- Maximum Merge Distance: 0.5
- Minimum Samples Per Cluster: 20
- Skip Factor: 10



The screenshot shows the 'Image Classification Wizard' window, specifically the 'Train' step. The window has a title bar with a question mark, a dropdown arrow, a maximize icon, and a close icon. Below the title bar is a progress indicator with seven circles; the fourth circle is filled blue, and the word 'Train' is centered below it. The configuration area contains the following fields:

- Classifier:** A dropdown menu showing 'ISO Cluster'.
- Maximum Number of Classes:** A text input field containing '20'.
- Maximum Number of Iterations:** A text input field containing '80'.
- Maximum Number of Cluster Merges per Iteration:** A text input field containing '5'.
- Maximum Merge Distance:** A text input field containing '0.5'.
- Minimum Samples Per Cluster:** A text input field containing '20'.
- Skip Factor:** A text input field containing '10'.



The maximum number of classes (clusters) should be more than the number of classes in the schema. A recommended practice would be two or two and a half times as many classes. In this example, there are 10 classes in the baseline schema (NLCD2011), so 20 classes (clusters) are selected.

For the maximum number of iterations, another generalized recommendation is to provide enough iterations for convergence. For this example, you are selecting four times the number of classes (clusters). The trade-off for including more iterations is that processing time increases.

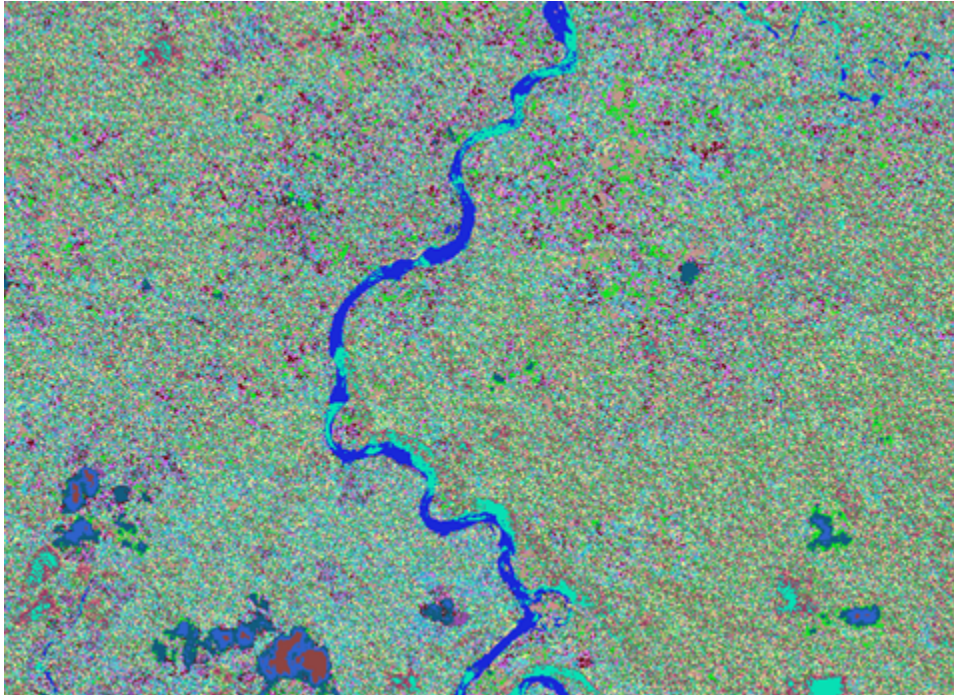
- b** Click Run.



This process may take a few minutes to complete.

- c** After the process is complete, at the bottom of the Image Classification Wizard pane, expand Train: Region_RioMira.

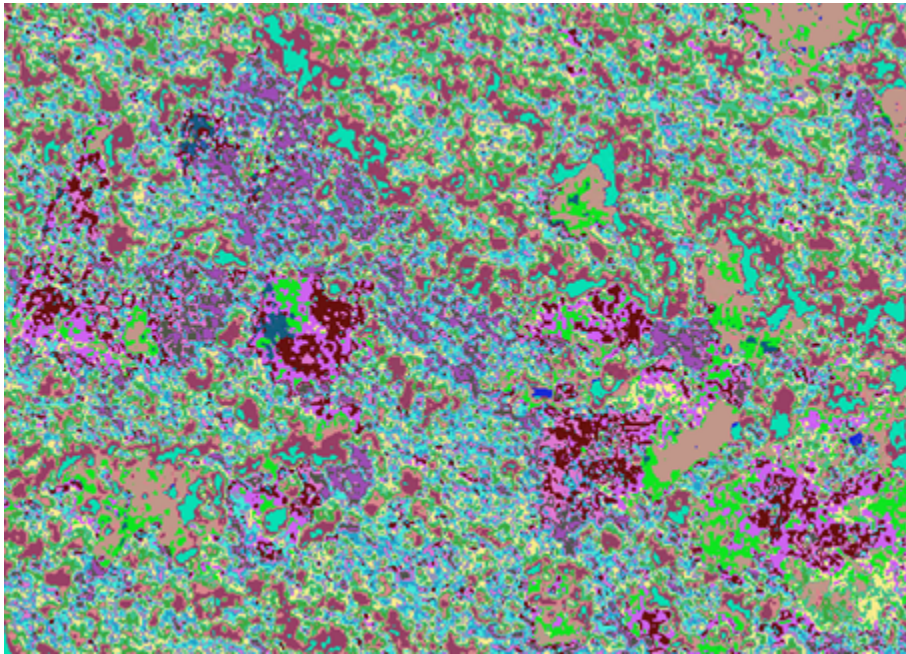
3. How many iterations did ISO Cluster complete?



The colors in your map may differ from the preceding graphic.

When complete, this new preview classified layer will automatically be added to your map and can be used to evaluate your initial clusters. You can quickly evaluate the results of your initial clustering by turning the new preview layer on and off. There are many variables in the unsupervised classification process, so the result may include confusion and misclassified pixels. To assess how well the clustering performed, you can use an area in the image suspected of illicit cultivation. Using an area of easily identifiable features allows you to see the type of clustering and separation for better evaluation.

- d From the Map tab, zoom to the Cultivation Site 1 (Potential) bookmark.



Examining this site does not immediately reveal much. The resulting classified layer is very speckled and even confusing. Interpreting this information can be difficult. However, you can see patterns—clusters that might be irregular agriculture—begin to emerge.

- e Press the L key to turn the preview layer on and off.





If this feature does not initially work, click in the Image Classification Wizard pane to make it the active window.

f Evaluate the clusters in this area.

4. What observations can you make about these initial clustering results in this area?

You are satisfied that there is enough separation in this area as a first-run result. For a more rigorous evaluation, you would perform this same type of workflow in multiple areas of the image or study area to determine whether you should rerun ISO Cluster a second or third time. For the purposes of this exercise, however, these results are sufficient.

Step 3: Classify the image

In this step, you will use the initial clusters identified in the Train step of the wizard to classify your image.

- a** In the Image Classification Wizard, for the Train step, click Next.
- b** For the Classify step, for Output Classified Dataset, type **Classified_RioMira**.
- c** Leave the other fields blank and click Run.



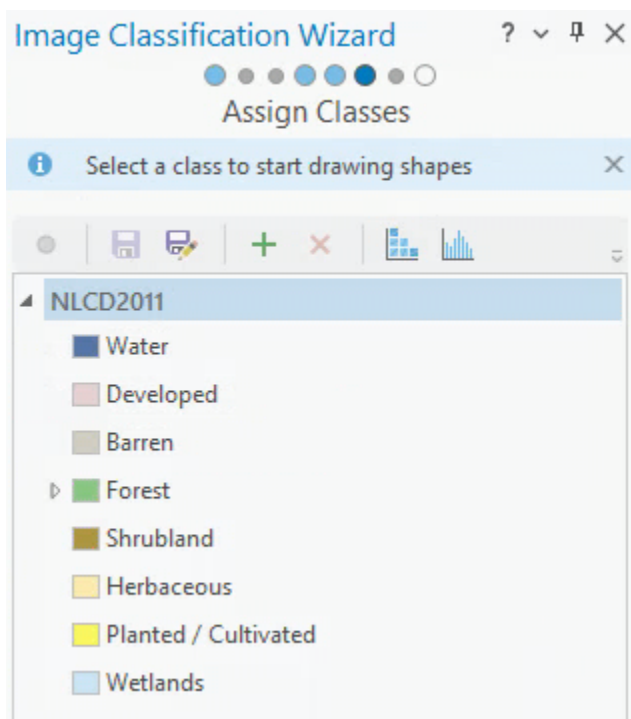
This process may take a minute or two to finish.

When this process is complete, the new classified image is added automatically to your map. The colors may change, but the classes based on the initial clusters will be the same. In the next step, you will begin assigning thematic values to these clusters.

Step 4: Assign classes

A new layer is added to your map as Classified_RioMira. As you assign new classes to your clusters, they will automatically change to reflect the new class assignments in this preview layer.

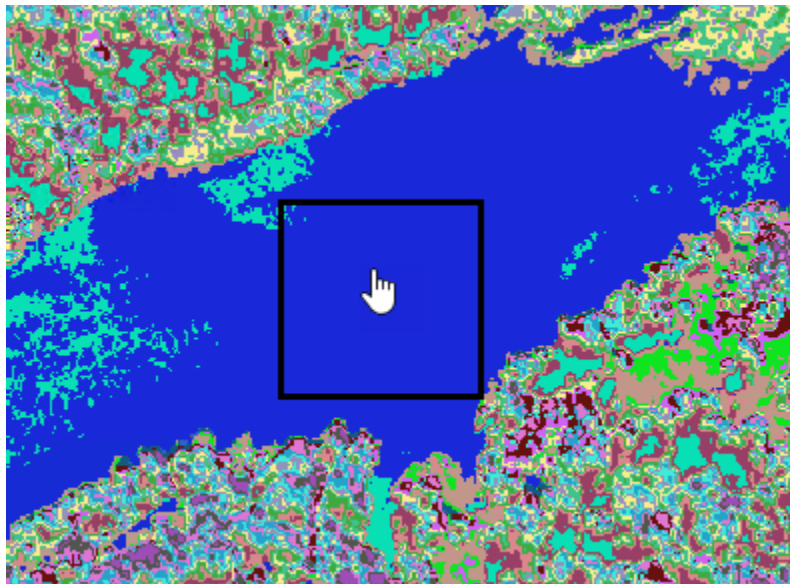
- a In the Contents pane, turn off and collapse both the Classified_RioMira and the Preview_Classified_ISO_20_80_20_10_5_0.5 layers.
- b In the Image Classification Wizard, click Next.
- c For the Assign Classes step, expand NLCD2011, if necessary.



The river is one of the easiest land cover features to identify in this image. You will begin by assigning the water class in your layer.

- d From the Map tab, zoom to the River Class Assign bookmark.

- e In the map, click the area specified in the following graphic to see its pop-up information.

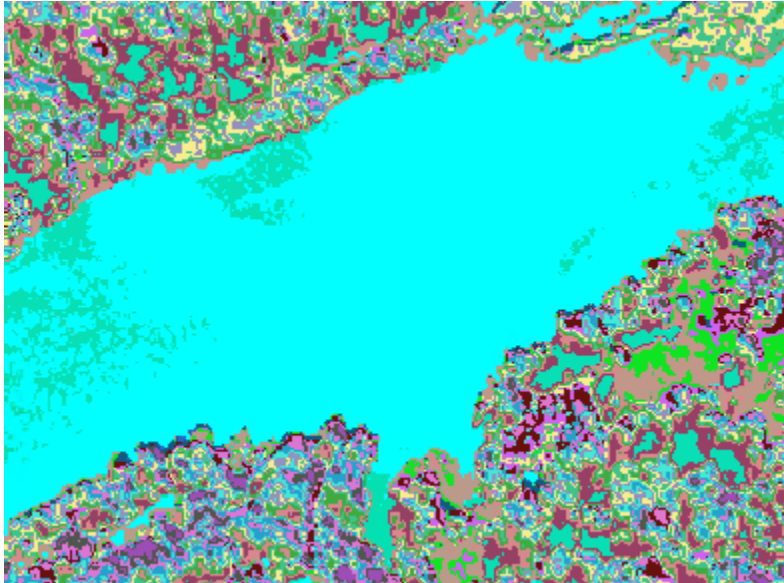


The colors in your map may differ from the preceding graphic when using this process.

5. What is the Class_name value for this cluster?

- f Close the pop-up window.

- g** In the Image Classification Wizard, on the Assign Classes page, in the Old Class and New Class table, click the gray box to the left of the Old Class 13 entry to highlight the class pixels in cyan in the map.

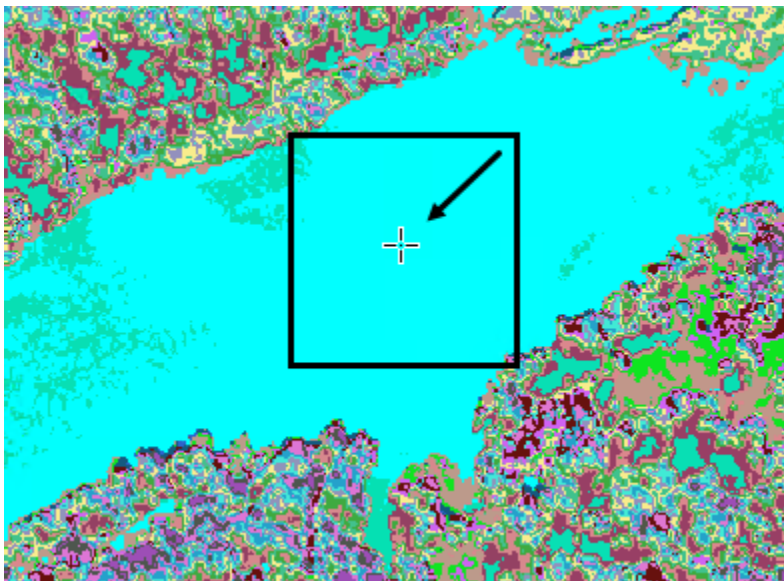


- h** In the NLCD2011 group, click Water.

The drawing shapes and the Assign tool are now active.

- i** Click the Assign button .

- j** In the map, move your pointer, which will change to a crosshairs symbol , over the river area, as indicated in the following graphic.



k Click to assign this cluster (13) to the Water class.

6. In the Image Classification Wizard, what changed in the New Class field for class 13?

7. In the Contents pane, what happens to Class_name 13?

8. How many classes are showing in the Preview_UnsupervisedAssignClasses layer?

l In the Image Classification Wizard, in the Old Class and New Class table, press the Ctrl key and click the gray box to the left of the Old Class 13 entry to deselect the feature in the map.

m Save your project.

Assigning the Old Class 13 to the Water class also updated the color symbology. The NLCD2011 default color symbology is updated automatically in the map and the New Class column. Depending on your color scheme, this update might not be easy to observe.

Step 5: Add new classes and subclasses to the schema

Before you can assign the remaining Old Classes to their New Class values, you will need to create a few new classes and subclasses to your existing schema. You will now add a Shadow class and a Cloud class to the NLCD2011 schema.

a In the Image Classification Wizard, in the NLCD2011 group, click NLCD2011.

b Click the Add New Class button .

c In the Add New Class pane, set the following parameters:

- Name: **Shadow**
- Value: **01**
- Color: Gray 80% (row 9, column 1)

- Alias: **Shadow/Mixed**
- Description: **This class is shadow or mixed. This class must be re-evaluated.**

Image Classification Wizard ? v f X

← Add New Class

Name
Shadow

Value
01

Color
[Black swatch]

Alias
Shadow/Mixed

Description
This class is shadow or mixed. This class must be re-evaluated.

- d Click OK.
- e Use this same process to create another new class under the NLCD2011 group with the following parameters:
 - Name: **Cloud**
 - Value: **05**
 - Color: Arctic White (row 1, column 1)
 - Alias: **Cloud/Mist**
 - Description: **Mixed class of cloud and mist.**



Before adding the next new class, ensure that you select NLCD2011 to create the new class as a main class, not as a child class of Shadow.

The current land cover schema only has one class for Planted/Cultivated. You are not restricted to the classes in this schema. ArcGIS Pro allows you to add new classes to account for variations and additional classes, as needed.

f In the Image Classification Wizard, in the NLCD2011 group, right-click Planted / Cultivated and choose Add New Class.

g In the Add New Class pane, set the following parameters:

- Name: **Illicit Cultivation Area 1**
- Value: **81**
- Color: Solar Yellow (row 3, column 5)

- Alias: **Mature (Mid-Season)**
- Description: **Potential illicit cultivation areas (Coca). June.**

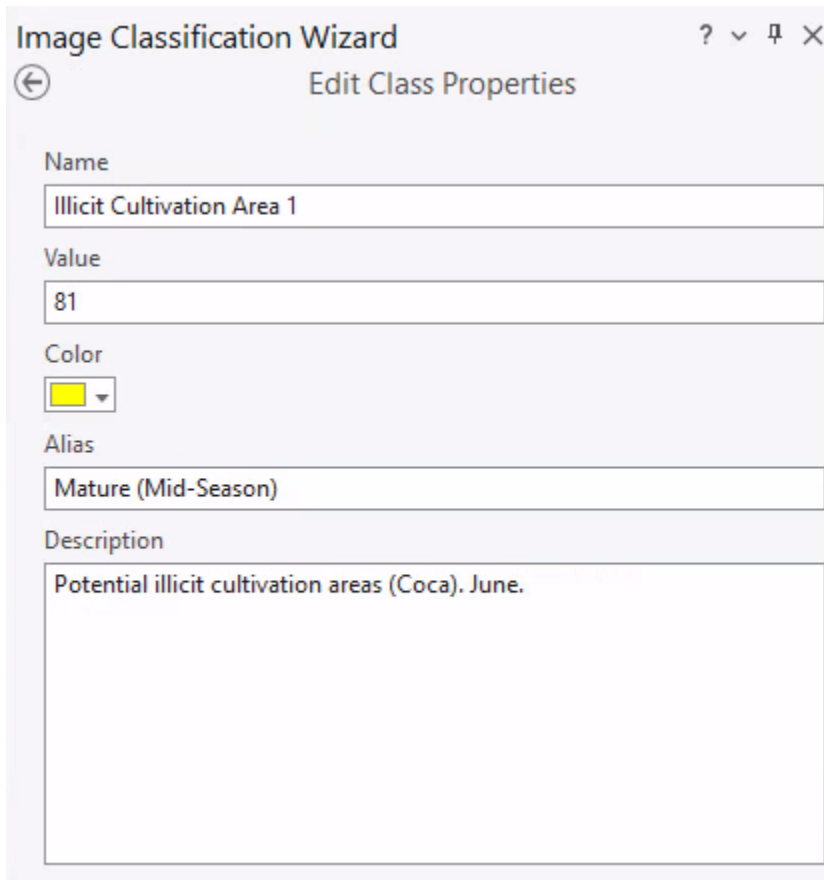


Image Classification Wizard ? v f X

← **Edit Class Properties**

Name
Illicit Cultivation Area 1

Value
81

Color
[Yellow]

Alias
Mature (Mid-Season)

Description
Potential illicit cultivation areas (Coca). June.

h Click OK.

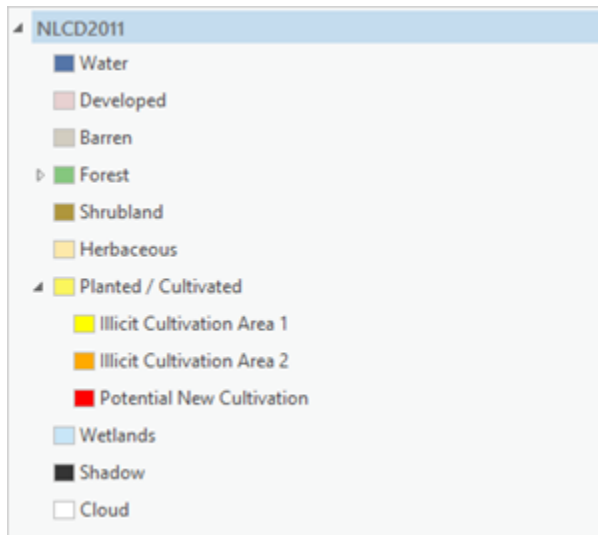


In this instance, the Add New Class pane shows that the new class is a subclass of the parent class of Planted / Cultivated.

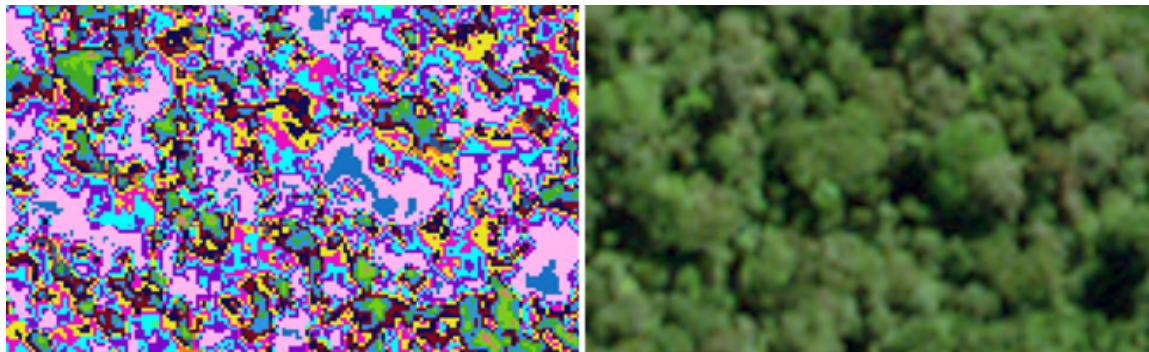
i Use this same process to create two more new subclasses under the Planted / Cultivated parent class with the following parameters:

- Name: **Illicit Cultivation Area 2**
- Value: **82**
- Color: Electron Gold (row 3, column 4)
- Alias: **Mature (Near Harvest)**
- Description: **Potential illicit cultivation areas (Coca). June.**

- Name: **Potential New Cultivation**
- Value: **83**
- Color: Mars Red (row 3, column 2)
- Alias: **New Growth**
- Description: **Potential new cultivation areas (Coca). June.**



j From the Map tab, zoom to the Forest Class Assign bookmark.



k On your own, use what you have learned to examine the classes in this area.

9. Based on your assessment, which classes appear to be present in this area?

- 1 On your own, assign the following old Class_names to the Forest class and the Shadow class using the workflow performed in the previous step.



See the Hint that follows for more information.

Old Class	New Class
1	Forest
4	Forest
8	Forest
11	Forest
17	Forest
19	Forest

Old Class	New Class
2	Shadow
18	Shadow

Hint: The easiest way to identify where a class is located in your map is to click the gray box to highlight the class pixels in cyan in the map.

As before, the New Class fields in the table are updated with the new class assignments. The Contents pane also updates automatically.

10. How many classes are now visible in the Preview_UnsupervisedAssignClasses layer?

- m From the Map tab, in the Selection group, click Clear to clear your selected class, if necessary.

- n** Save your project.

In this step, you added new classes and began to assign class values. You will continue to assign values in the next step.

Step 6: Assign the remaining class values

In this step, you will repeat the process of assigning classes to the remaining old classes to their new classes categories.

- a** From the Map tab, zoom to the Cultivation Site 1 (Potential) bookmark.
- b** On your own, assign the new class values for this area, as shown in the following tables.

Old Class	New Class
0	Barren
6	Barren

Old Class	New Class
5	Herbaceous
9	Herbaceous
14	Herbaceous

Old Class	New Class
7	Potential New Cultivation
12	Illicit Cultivation Area 2
15	Illicit Cultivation Area 1

- c** From the Map tab, in the Selection group, click Clear to clear your selected class.
- d** Return to the Cultivation Site 1 (Potential) bookmark, if necessary.

11. How many classes are now visible in the Preview_UnsupervisedAssignClasses layer?

12. Which classes remain unassigned?

The remaining classes are all either cloud or mist.

- e In the Contents pane, right-click the Preview_UnsupervisedAssignClasses layer and choose Zoom To Layer.
- f In the Image Classification Wizard, for the Assign Classes step, in the Old Class/New Class table, click the gray box to the left of the Old Class 16.

These areas that are selected in the southwest quadrant of the image are the clouds.

- g In the map, zoom to the selected area.
- h On your own, assign the Cloud class to the remaining classes.

Old Class	New Class
3	Cloud
10	Cloud
16	Cloud

13. How many classes are now visible in the Preview_UnsupervisedAssignClasses layer?

- i From the Map tab, in the Selection group, click Clear to clear your selected class, if necessary.
- j From the Map tab, zoom to the Cultivated Area Class bookmark.
- k In the Image Classification Wizard, click Next.

- 1** Save your project.

All clusters from the original ISO Cluster process have now been assigned to land cover classes.

Step 7: Reclassify mixed and misclassified pixels

The final step in the Image Classification Wizard is the Reclassifier step. As you observed, unsupervised pixel-based classification can result in a lot of misclassified pixels. Sometimes, this result is also called mixed pixels because different effects (atmospheric or otherwise) may lead to confusion in an area of otherwise homogeneous land cover.

One way to alleviate this problem would be to mask the confused pixels and rerun the ISO Cluster algorithm a second time. Another way to correct this problem would be to reclassify these pixels.

For this exercise, you will skip the Reclassifier step in the Wizard and instead use the Pixel Editor to reclassify small portions of your result. For reclassifying pixels in a classified raster, the Pixel Editor offers more options than the Reclassifier step in the Image Classification Wizard. The Pixel Editor offers several ways to perform this portion of the workflow. In this exercise, you will use two of the most common ways. You will reclassify an object (a contiguous group of pixels), and you will reclassify pixels based on a user-defined region.

Because you will not be performing the Reclassifier step in the Image Classification Wizard, you will create a new classified raster dataset as your last step.

- a** Near the bottom of the Image Classification Wizard, for Final Classified Dataset, type **Illicit_Crop_Detection_FirstRun**.

- b** Click Run.

After the Reclassifier step finishes, the new layer is automatically added to your map.

- c** Click Finish.

d In the Contents pane, remove the following preview layers that were generated by the Image Classification Wizard:

- Preview_Reclass
- Preview_UnsupervisedAssignClasses
- Preview_Classified_ISO_20_80_20_10_5_0.5_0022

e In the Contents pane, select the Illicit_Crop_Detection_FirstRun layer.

f From the Imagery tab, in the Tools group, click Pixel Editor.



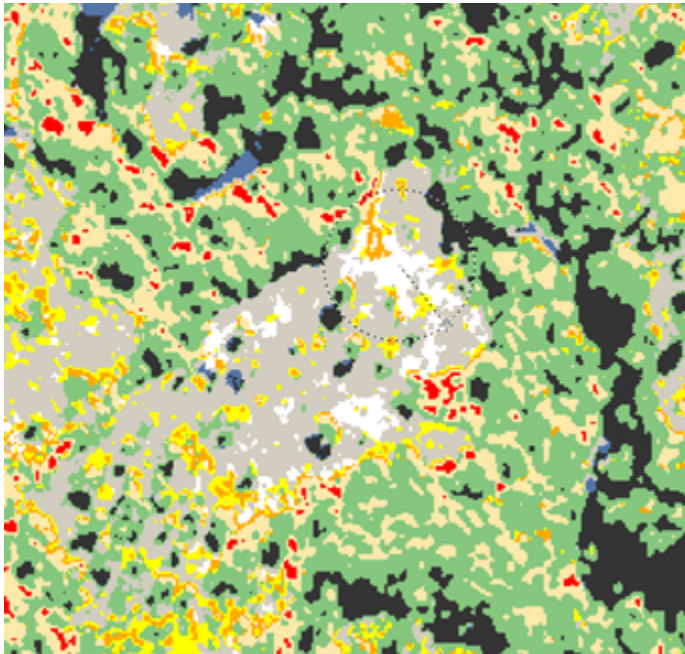
The Pixel Editor opens as the second tab on the ribbon, not as a pane, and becomes the active tab.

g From the Pixel Editor tab, in the Edit group, click the Reclassify down arrow and choose Reclassify Object.

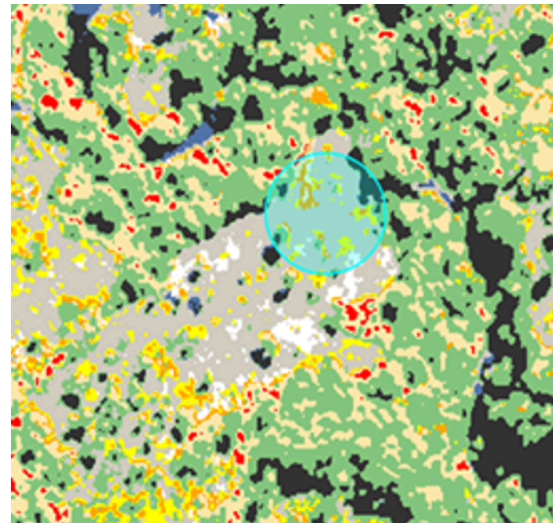
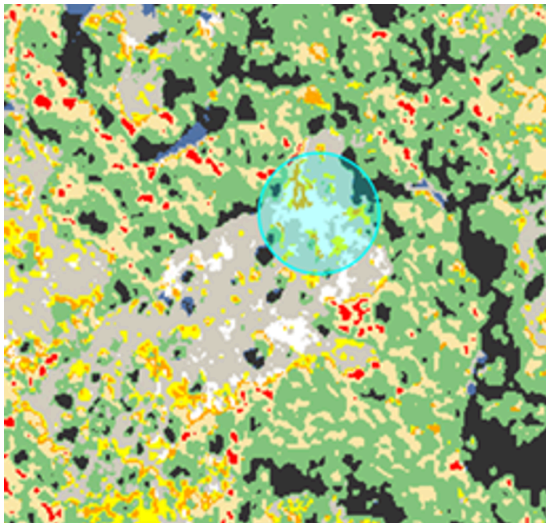
h In the Edit group, set the following parameters:

- Current Class: Any
- New Class: Barren

- i In the map, click and extend a circle around the misclassified pixels, as specified in the following graphic.



After you extend the circle, releasing your click completes the circle.

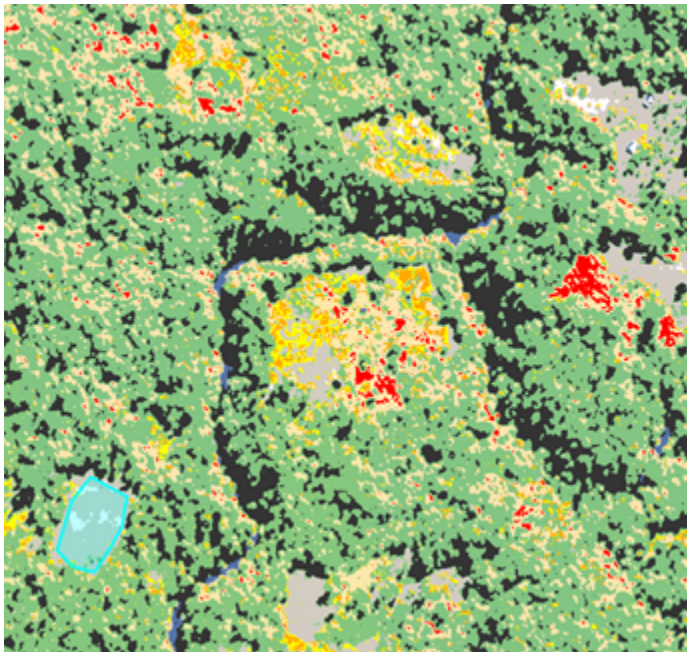


On the left are the pixels misclassified as Cloud. On the right, only the single contiguous Cloud object class is reclassified to Barren. You will not see a cyan circle in your map. This graphic is intended to aid orientation and clarity.

Because the Cloud class (object) is the dominant object within the defined area, it is the only object reclassified to the new class of Barren.

You can also reclassify misclassified pixels based on a region. You can either reclassify all pixels in a user-defined region, or just reclassify from one single class to another.

- j From the Map tab, zoom to the Cultivation Site 2 (Potential) bookmark.
- k From the Pixel Editor tab, in the Edit group, click the Reclassify down arrow and choose Reclassify Region.
- l Verify that the following parameters are still set:
 - Current Class: Any
 - New Class: Barren
- m Draw a polygon around the misclassified pixels, as specified in the following graphic.

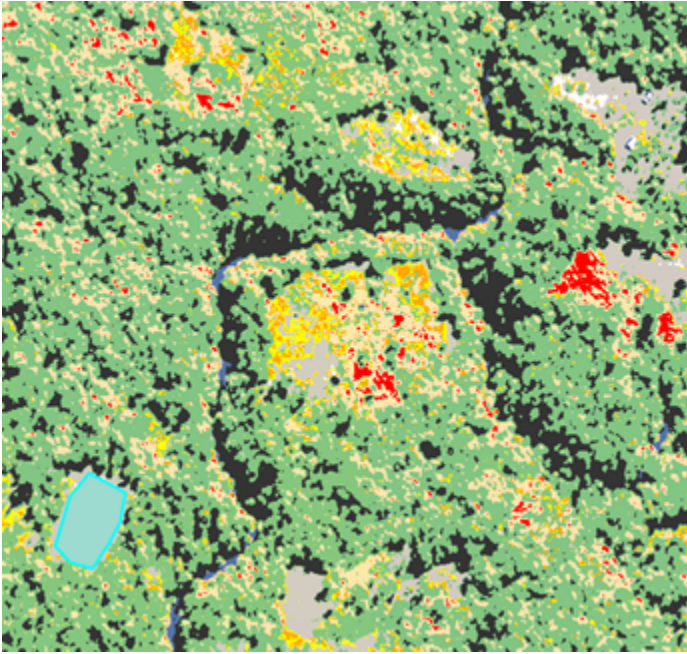


You will not see a cyan polygon in your map. This graphic is intended to aid orientation and clarity.

- n Double-click to finish the polygon.

This particular example contains cloud and mist; it is transparent enough, however, that you can reclassify the entire area with some confidence to the surrounding Barren class.

- o Notice the polygon that is highlighted in the map.



You will not see a cyan polygon in your map. This graphic is intended to aid orientation and clarity.

If you decide not to use this change, you can undo the edit and the Old Class values will be restored.

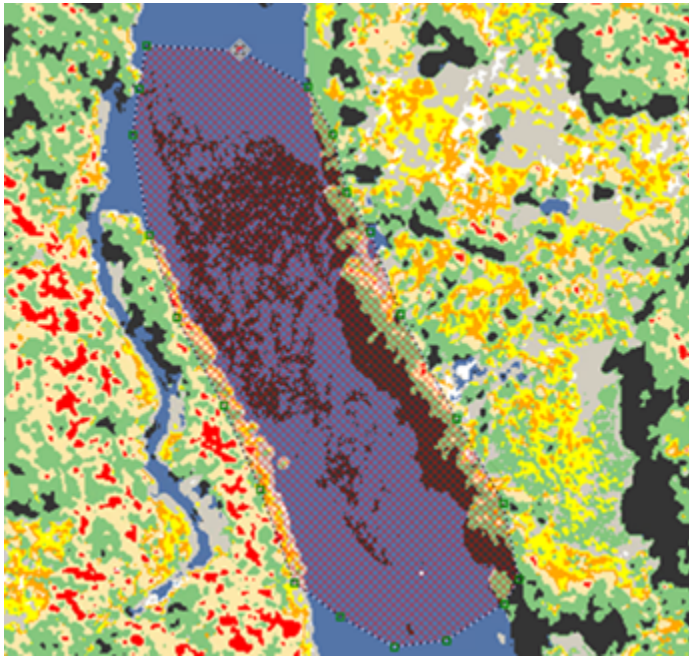
- p From the Quick Access toolbar, click Undo .
- q At this point, you can either redraw the polygon, or redo the edit.

Hint: From the Quick Access toolbar, click the Redo button  to reenable your edit.

You can also change a single class inside a polygon.

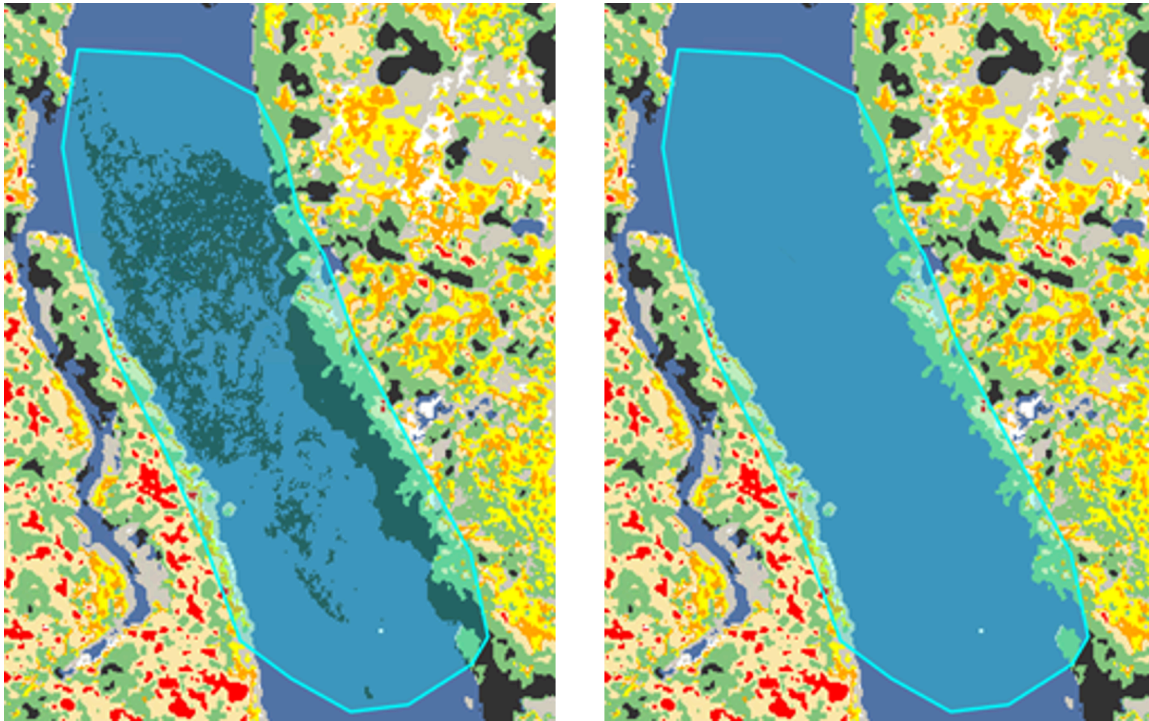
- r From the Map tab, zoom to the Water Reclassify bookmark.
- s From the Pixel Editor tab, in the Edit group, set the following parameters:
 - Current Class: Shadow
 - New Class: Water

- t Ensure that the Reclassify Region tool is still active, and then draw a similar polygon to the one shown in the following graphic.



You will not see a red polygon in your map. This graphic is intended to aid orientation and clarity.

- u Double-click to close the polygon.



On the left are the pixels classified as Shadow. On the right, the pixels have been reclassified as Water. You will not see a cyan polygon in your map. This graphic is intended to aid orientation and clarity.

Because the Pixel Editor changes the pixel values of your classified raster, you have the option to discard your edits, save your edits, or save your edits to a new classified raster dataset. For this exercise, you are satisfied with the edits that you performed, so you will save your edits directly to your current classified raster.

- v From the Pixel Editor tab, in the Save group, click Save.
- w From the Pixel Editor tab, click Close Pixel Editor.

There are challenges to performing unsupervised classification. As previously stated, it is often a very iterative process. When you have limited information about an area (or in this case, a single image for this type of illicit crop analysis), there can be many unforeseen challenges to overcome.

The result of this particular classification is merely the first step in a larger analysis that can be provided to leadership. As an interim result, your initial analysis can provide commanders with a quick-look assessment of the challenges eradicating the crops in time. This analysis is one step

in the process and should not be understood as a finalized, authoritative, or definitive analysis of the area in question.

-  Close the open map, saving if prompted.
-  Save your project and leave ArcGIS Pro open for the next exercise.

Workflow review

Even when using the guided workflow of the Image Classification Wizard, it is still important to understand what occurs in each step.

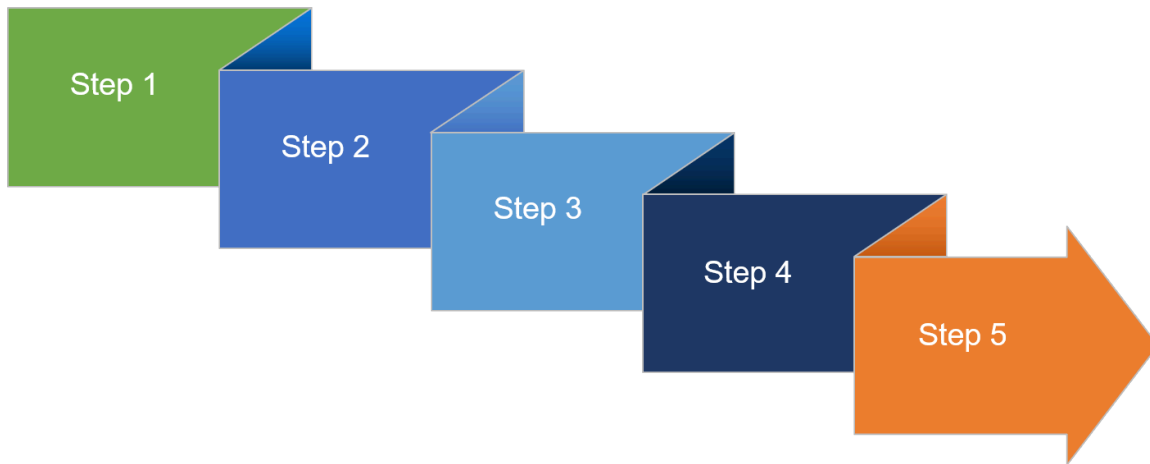


Figure 5.2. There are five workflow steps.

1. Assign the correct order for the five steps of the unsupervised pixel-based classification workflow:

- Assign classes to the schema
- Categorize the imagery into classes
- Evaluate classes
- Determine the type and method
- Choose the number of clusters

Answers to lesson 5 questions

Exercise 5: Perform an unsupervised pixel-based classification (page 5-3)

1. In the Illicit Crops map, what type of layer is the Region_RioMira dataset?

The Region_RioMira layer is a mosaic dataset.

2. In the Train step, what are the Classifier options available to you?

ISO Cluster is the only option available through the wizard.

3. How many iterations did ISO Cluster complete?

It completed 21 of the 80 maximum iterations.

4. What observations can you make about these initial clustering results in this area?

Answers will vary. Overall, these clusters separate the cultivated areas well, but there is still a lot of confusion in the forested areas. There is a possibility that some of these areas are indeed cultivated areas, but it is not likely that they all are. The most encouraging artifact in this image is the separation of clusters in the cultivated areas, which may be an indicator of illicit grow locations intermingled with the regular crops.

5. What is the Class_name value for this cluster?

The Class_name value is thirteen (13).

6. In the Image Classification Wizard, what changed in the New Class field for class 13?

The new class of Water is automatically added to this column.

7. In the Contents pane, what happens to Class_name 13?

It is automatically updated to a new Class_name of Water.

8. How many classes are showing in the Preview_UnsupervisedAssignClasses layer?

There are 20 classes.

Answers to lesson 5 questions (continued)

9. Based on your assessment, which classes appear to be present in this area?

The two predominant classes in this area are Forest and Shadow. Depending on the canopy level, you might be able to determine that the Herbaceous class undergrowth can be observed, too.

10. How many classes are now visible in the Preview_UnsupervisedAssignClasses layer?

There are only 14 classes. The previous Class_names are combined into the new Forest class and the Shadow class as single entities.

11. How many classes are now visible in the Preview_UnsupervisedAssignClasses layer?

There are 11 classes.

12. Which classes remain unassigned?

Class 3, Class 10, and Class 16 remain unassigned.

13. How many classes are now visible in the Preview_UnsupervisedAssignClasses layer?

There are only nine classes.

Workflow review (page 5-30)

1. Assign the correct order for the five steps of the unsupervised pixel-based classification workflow:

- Assign classes to the schema
- Categorize the imagery into classes
- Evaluate classes
- Determine the type and method
- Choose the number of clusters

1. Determine the type and method
2. Choose the number of clusters
3. Categorize the imagery into classes
4. Assign classes to the schema
5. Evaluate classes

Image classification can be a powerful tool in defense and intelligence analysis. In ArcGIS Pro, you can perform supervised object-based classification to transform imagery into information. You can use the resulting thematic layers for dissemination or further analysis.

Topics covered

- Training Samples Manager

- Supervised object-based classification

Supervised object-based classification

You have more input into the supervised object-based classification workflow, which gives you more control over the classification results. Just as with unsupervised pixel-based classification, you can perform supervised object-based classification using the Classification Wizard or with individual geoprocessing tools or raster functions.

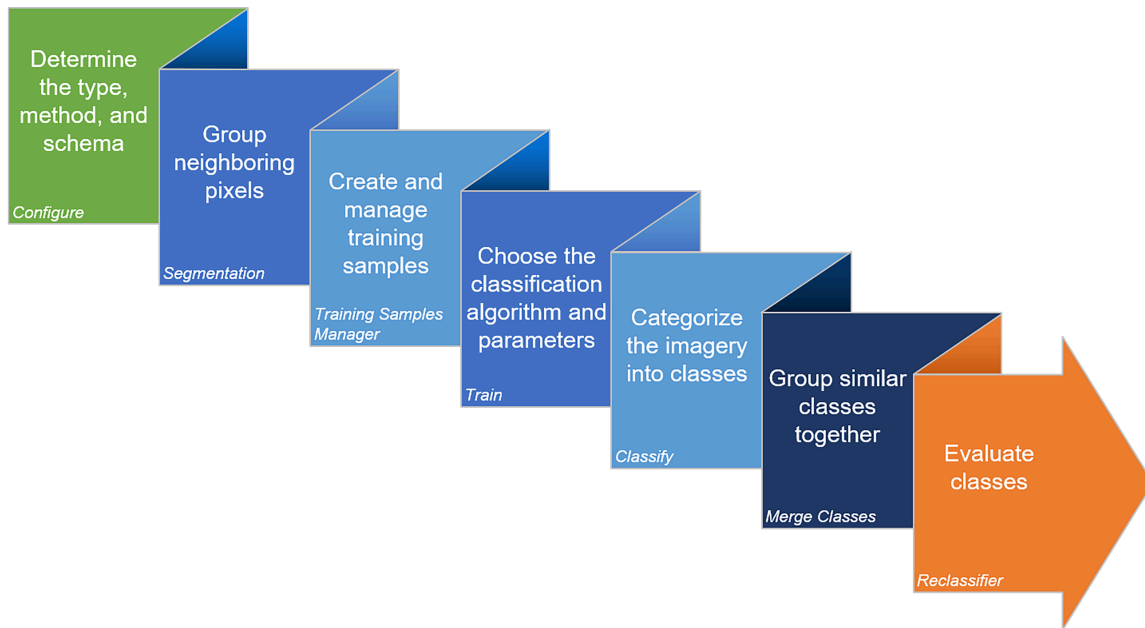


Figure 6.1. The Image Classification Wizard provides a step-by-step workflow for a supervised object-based classification.

Exercise 6

Perform a supervised object-based classification



This scenario is completely fictitious in nature and should not be viewed as a representation of an actual prior operation.

As a GEOINT analyst attached to a National Guard unit, you are assigned to the California Fires Emergency Operations Center (EOC), providing augmented support to active wildfires. You are classifying imagery to identify damage from one of the recent fires. You previously used the original data to create a segmented raster, and you will use this segmented raster to collect training samples for your supervised object-based image classification. Using the Training Samples Manager, you will create training samples and generate an Esri classifier definition file.

After you collect your classifier definition file, you will finish the image classification process to identify building damage and provide a thematic layer to your leadership.

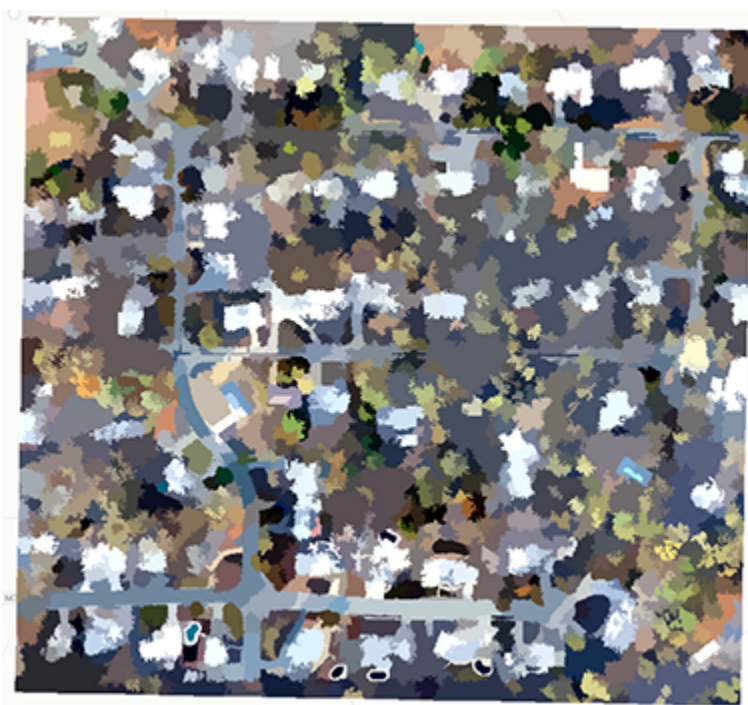
In this exercise, you will perform the following tasks:

- Create training samples with the Training Samples Manager.
- Create an Esri classifier definition file.
- Create a supervised object-based classification.

Step 1: Add input data

In this step, you will add the input raster that was obtained using a UAV of the damaged area, a segmented raster, and the training area polygon.

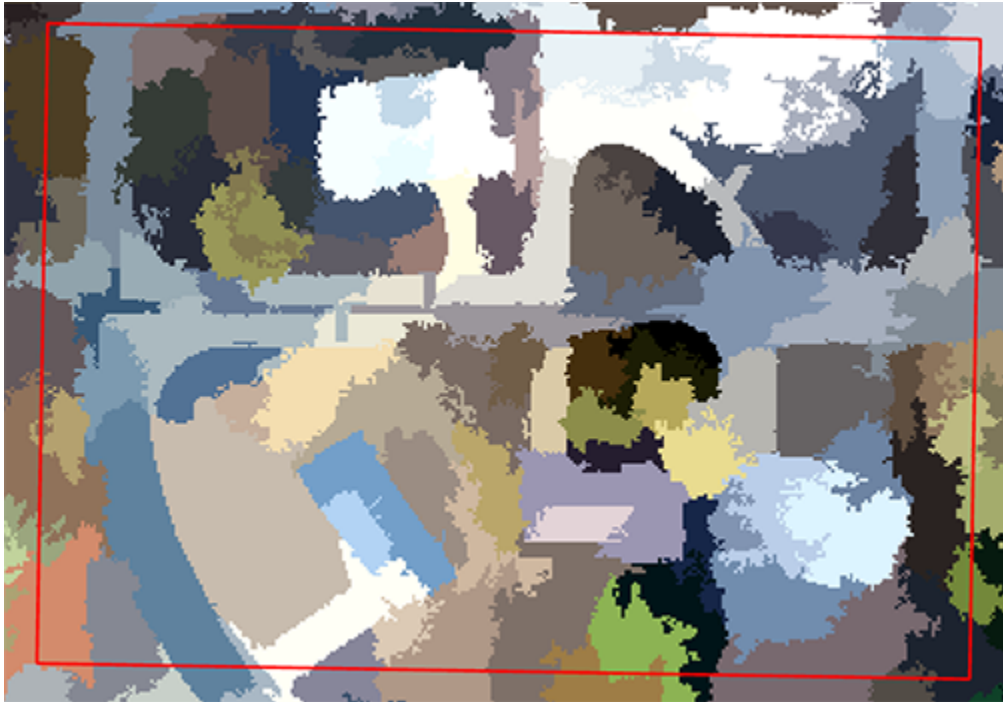
- a Restore ArcGIS Pro, if necessary, and then from the ribbon, click the Project tab.
- b Click Open, and then click Open Another Project.
- c Browse to **C:\EsriTraining\IMAD\Projects\DamageAssessment** and open the DamageAssessment project.
- d In the Catalog pane, expand Folders and Paradise.
- e Select both the ParadiseRecovery50.tif and SMS_165_10_200.tif files, and then right-click one of the files, point to Add To New, and choose Map to add them both to the map.



For this exercise, rather than create training samples of the whole raster, you will create training samples on a portion.

- f In the Catalog pane, from the Paradise folder, expand Classification.gdb and add the TrainingArea feature class to your map.

- g** Change the symbology of the TrainingArea layer to a no-color fill with a 1-point red outline.
- h** In the Contents pane, right-click the TrainingArea layer and choose Zoom To Layer.



The segments in the training area are fairly large, but many of the features are still recognizable.

Step 2: Evaluate the study area

Now that you have added the input data to your map, you are ready to evaluate the training area and determine the classes that you will represent.

- a** In the Contents pane, turn off the visibility of SMS_165_10_200.tif, the segmented raster.



- b** Zoom and pan around the training area and look for the different visible features.



Remember that the purpose of this image classification is to identify debris left from the fires. Be sure that you include damaged areas in your evaluation.

1. What types of burn damage are visible in the training area?

2. What are some classes that you could include in your schema?

You have evaluated the training area and determined classes that you can include in your schema.

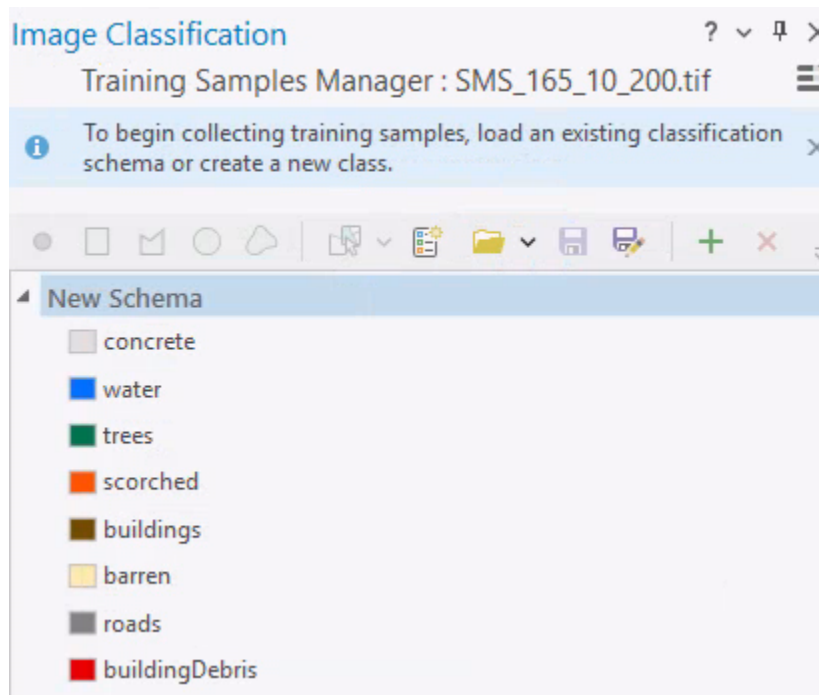
Step 3: Configure the Training Samples Manager

Now that you have evaluated the training area, you are ready to configure the Training Samples Manager.

- a In the Contents pane, make the segmented raster (SMS_165_10_200.tif) visible in the map and ensure that it is selected.
- b From the Imagery tab, in the Image Classification group, click Classification Tools and choose Training Samples Manager.

The default image classification schema is the NLCD 2011 schema. For this image classification, you have identified classes for the burn damage that are not within the schema. Rather than modify this schema, you will use a custom schema.

- c In the Training Samples Manager, click the Classification Schema button  and choose Browse To Existing Schema.
- d In the Load Schema dialog box, browse to **..\EsriTraining\IMAD\Projects\DamageAssessment**, select **ParadiseTrainingFinal_Schema.ecs**, and click OK.



The classification schema has been altered to the training classes in the provided training feature class. You will not find all these classes in the training area, but you can use this schema to create your training data.

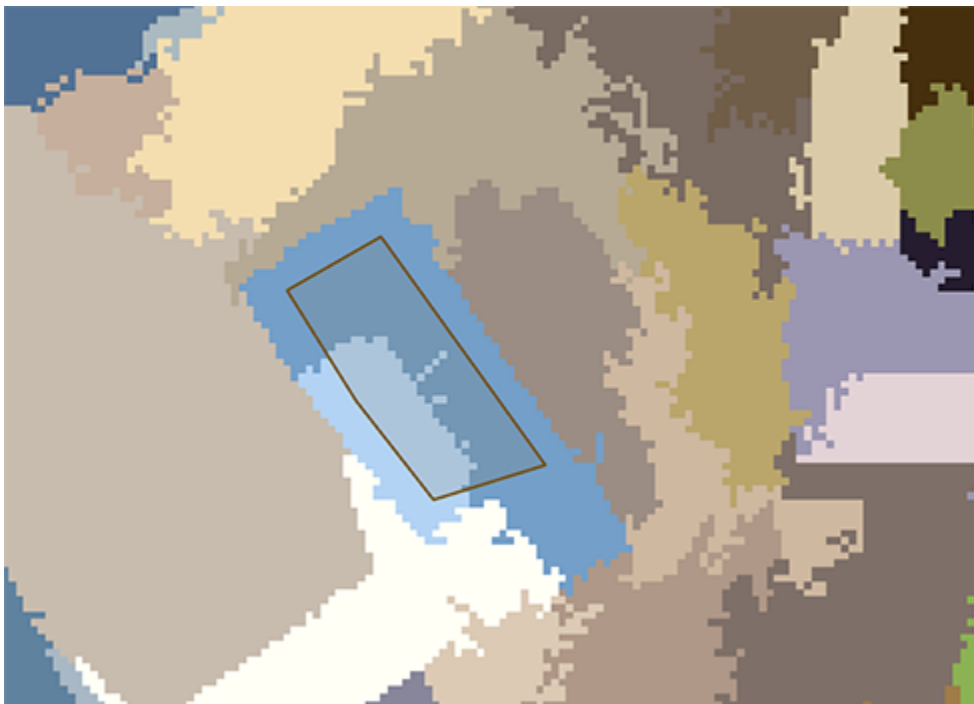
Step 4: Collect training samples

Now that the Training Samples Manager is configured, you are ready to start collecting training samples.



For most classifications, you would collect multiple training samples for each class. For this exercise, however, you will only collect a few training samples for each visible class.

- a In the Contents pane, ensure that the segmented raster (SMS_165_10_200.tif) is selected and that the layer is turned on.
- b In the Training Samples Manager, select Buildings and click the Polygon tool .
- c In the map, draw a polygon around one of the existing buildings.



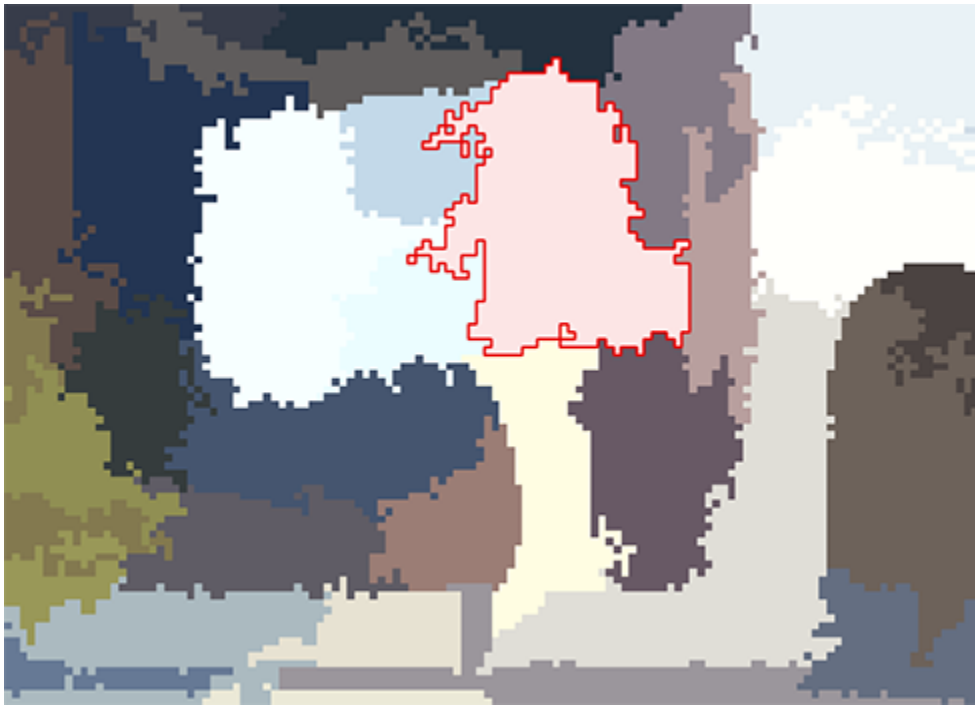
The training sample polygon symbology matches the symbology in the schema.



When using the Polygon tool, be sure to draw the polygon around more than half the segment for it to be considered in the classifier definition. When your training polygon covers less than 50 percent of the segment, it will not be considered by the classifier.

To be sure that your segment is used by the classifier, you will use the Segment Picker tool available in the Training Samples Manager.

- d Locate one of the burned buildings to use as a training sample.
- e In the Training Samples Manager, select the buildingDebris class, and then click the Segment Picker button .
- f If prompted, choose the segmented raster.
- g In the map, pause your pointer over a burned building, and then click a segment.



The outline of the training sample becomes the edge of the segment. This result is why having a properly segmented raster is important for an accurate image classification. When the segments combine multiple features, the classification results are not as accurate.

h Repeat these steps to collect a sample for the following classes:

- Scorched
- Concrete
- Roads

When you are satisfied with your training samples, you are ready for the next step.

Step 5: Save training samples

Now that you have created some training samples, you will save them to create the Esri classifier definition.

a In the lower section of the Training Samples Manager, click the Save As button .



Do not use the Save As button in the upper section. That one is used to save a schema and will not retain your training samples.

b In the Save A Copy Of Current Training Samples dialog box, browse to **..\EsriTraining\IMAD\Imagery\UnitedStates\Paradise\Classification.gdb** and save the feature class as **PracticeTrainingSamples**.

c Close the Training Samples Manager.

d Click Yes to save the modifications.

e Save your project.

You have saved your training samples.

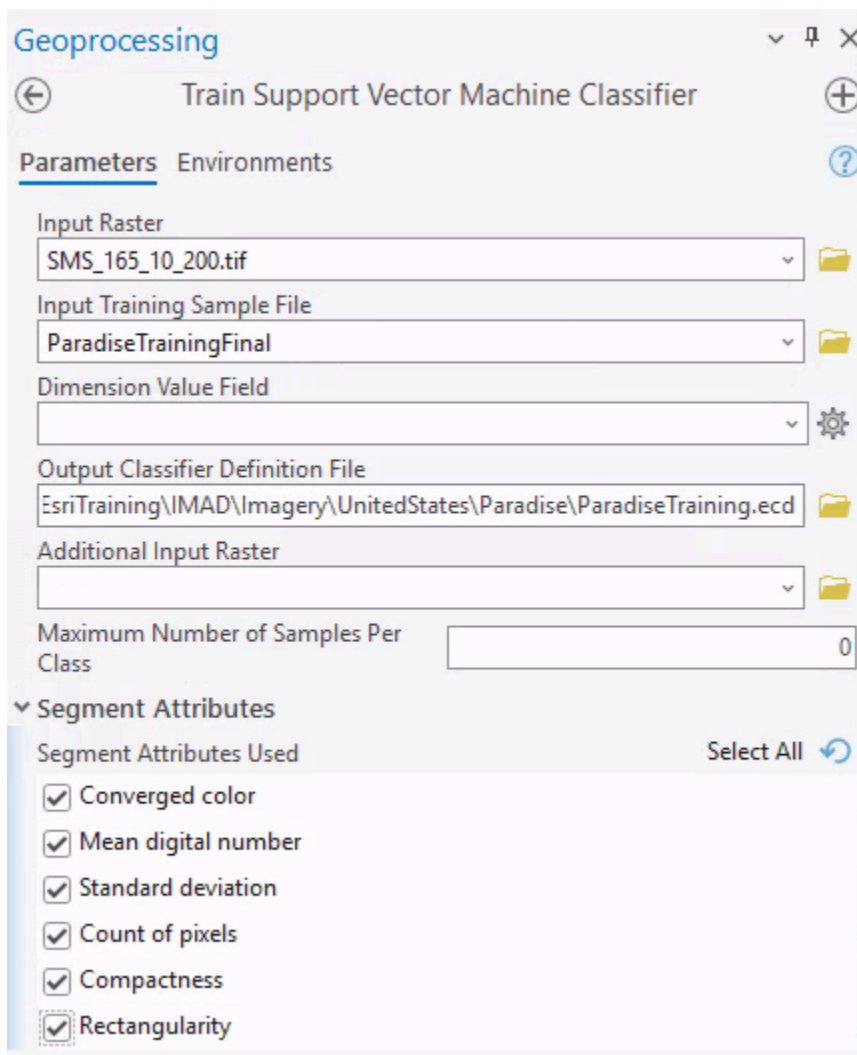
Step 6: Create a classifier definition

In this step, you will create the Esri classifier definition file based on the training data.

a From the Analysis tab, in the Geoprocessing group, click Tools.

b In the Geoprocessing pane, search for **support vector**.

- c Open the Train Support Vector Machine Classifier (Image Analyst Tools) tool and specify the following parameters:
- For Input Raster, choose SMS_165_10_200.tif.
 - For Input Training Sample File, browse to **..\EsriTraining\IMAD\Imagery\UnitedStates\Paradise\Classification.gdb\ParadiseTrainingFinal**.
 - For Output Classifier Definition File, browse to **..\EsriTraining\IMAD\Imagery\UnitedStates\Paradise**, and then for Name, type **ParadiseTraining.ecd** and click Save.
 - For Maximum Number Of Samples Per Class, type **0**.
 - Expand the Segment Attributes section, and then click Select All.



- d Click Run.



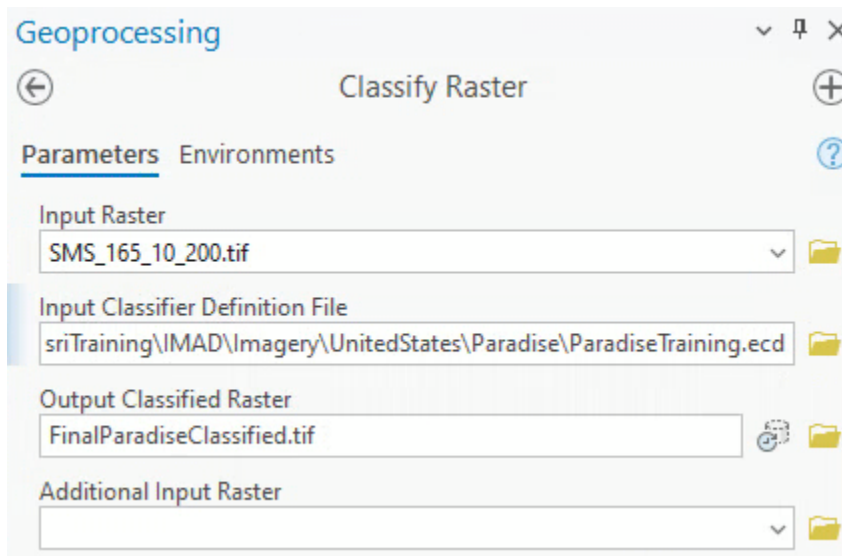
If you did not specify the .ecd extension for the output classifier definition file, there will be an error and the tool will not complete.

In this step, you created the Esri classifier definition file based on the training data.

Step 7: Create a classified thematic layer

In this step, you will create the classified thematic raster to perform the damage assessment.

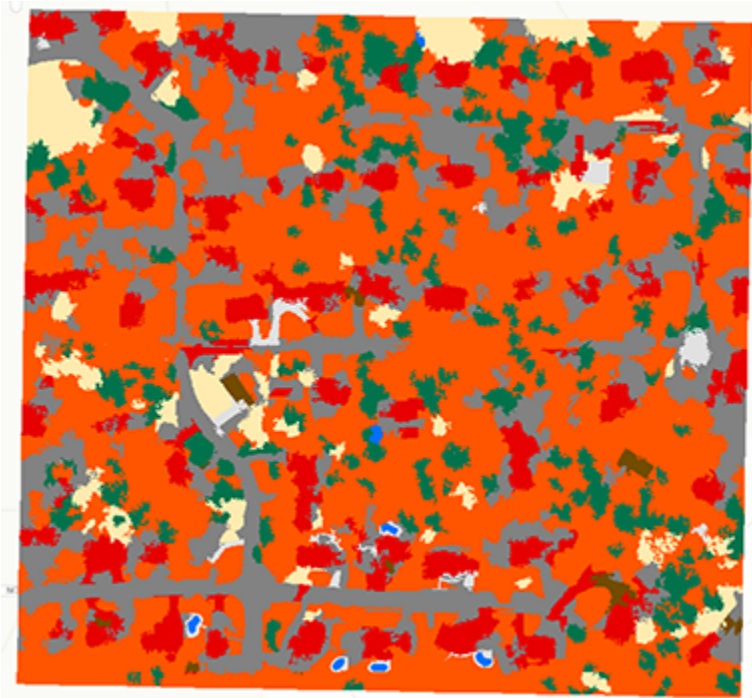
- a In the Geoprocessing pane, near the top-left corner, click the Back button , and then search for **classify raster**.
- b Open the Classify Raster (Image Analyst Tools) tool and specify the following parameters:
 - For Input Raster, choose SMS_165_10_200.tif.
 - For Input Classifier Definition File, browse to **..\EsriTraining\IMAD\Imagery\UnitedStates\Paradise\ParadiseTraining.ecd**.
 - For Output Classified Raster, browse to **..\EsriTraining\IMAD\Imagery\UnitedStates\Paradise**, and then for Name, type **FinalParadiseClassified.tif** and click OK.



- c Leave the remaining parameter blank and click Run.

The tool runs successfully but with a warning that states that the inter index raster was not found with the segmented raster and will need to be computed as a temporary raster.

- d In the Contents pane, turn off the TrainingArea layer and zoom to the full extent of the FinalParadiseClassified.tif layer.



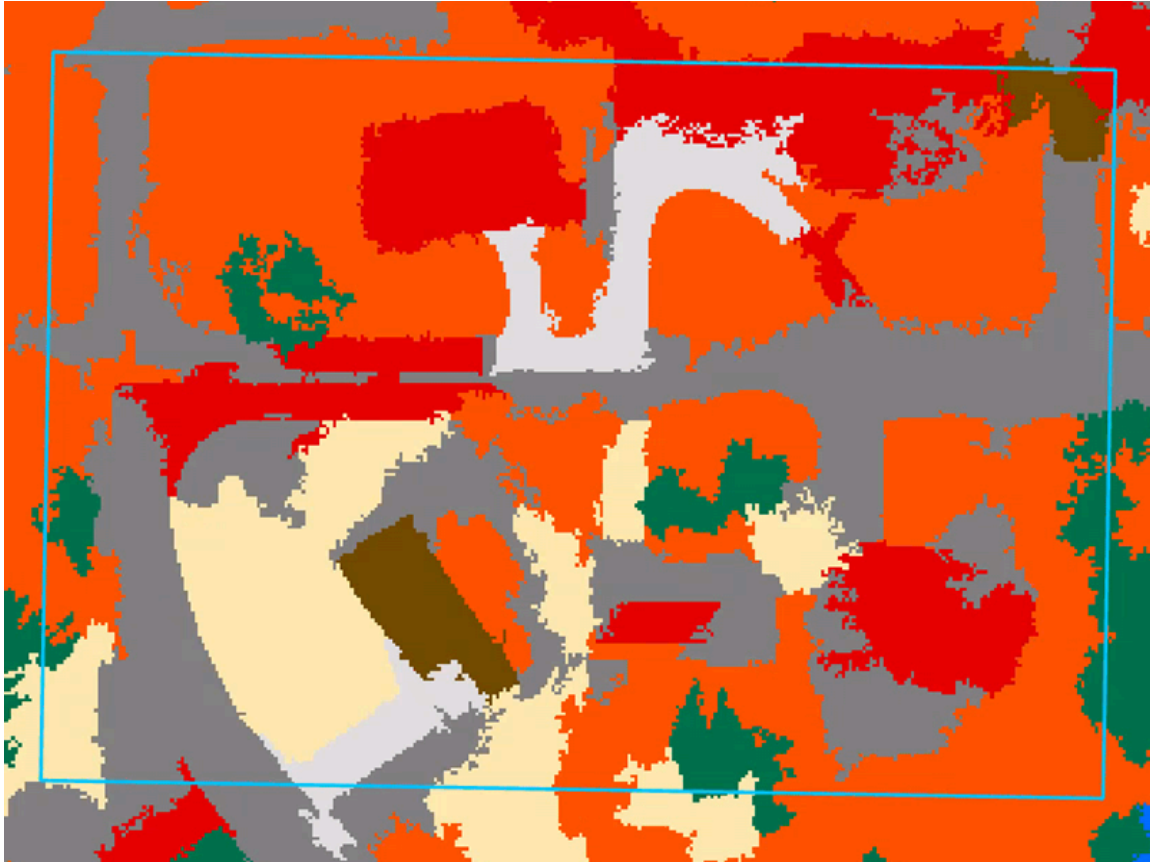
You have created a classified thematic raster. Overall, you are satisfied with the results. However, you have determined that some classes have been incorrectly classified. In the following step, you will reclassify areas that were misclassified.

Step 8: Reclassify pixels

Because you determined that some classes were not appropriately classed, you will use Pixel Editor to reclassify problematic areas.

- a In the Contents pane, turn on the TrainingArea layer.
- b Zoom to the TrainingArea layer.

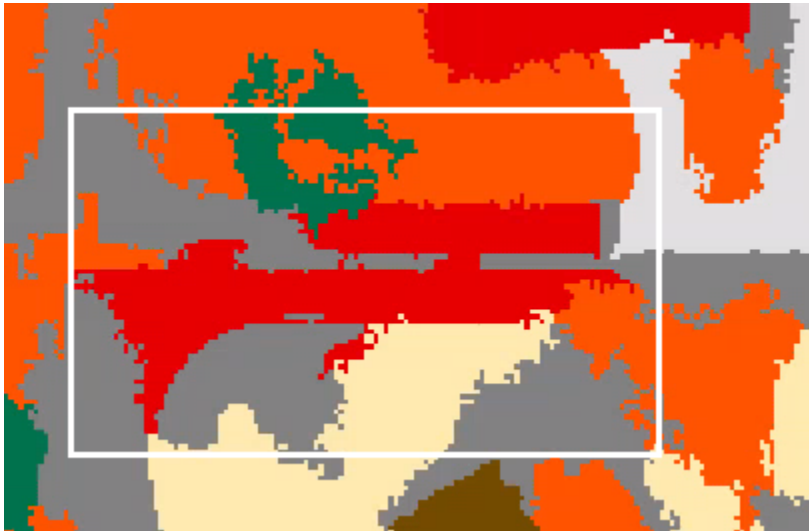
- c Change the symbology to a No Color fill and cyan blue outline, if necessary.



Within the TrainingArea polygon, there are misclassified building and road areas. To fix these areas, you will use Pixel Editor to reclassify the misclassified segments.

- d In the Contents pane, select the FinalParadiseClassified.tif layer.
- e From the Imagery tab, in the Tools group, click Pixel Editor.
 -  Pixel Editor opens as the second tab on the ribbon, not as a pane, and becomes the active tab.
- f From the Pixel Editor tab, in the Edit group, change Current Class to buildingDebris and New Class to Roads, if necessary.

- g Locate the segment classified as buildingDebris, as shown in the following graphic.



- h From the Pixel Editor tab, in the Edit group, click the Reclassify down arrow and choose Reclassify Region.
- i In the map, draw a polygon around the previously specified segment of the misclassified buildingDebris area, similar to the one in the following graphic.

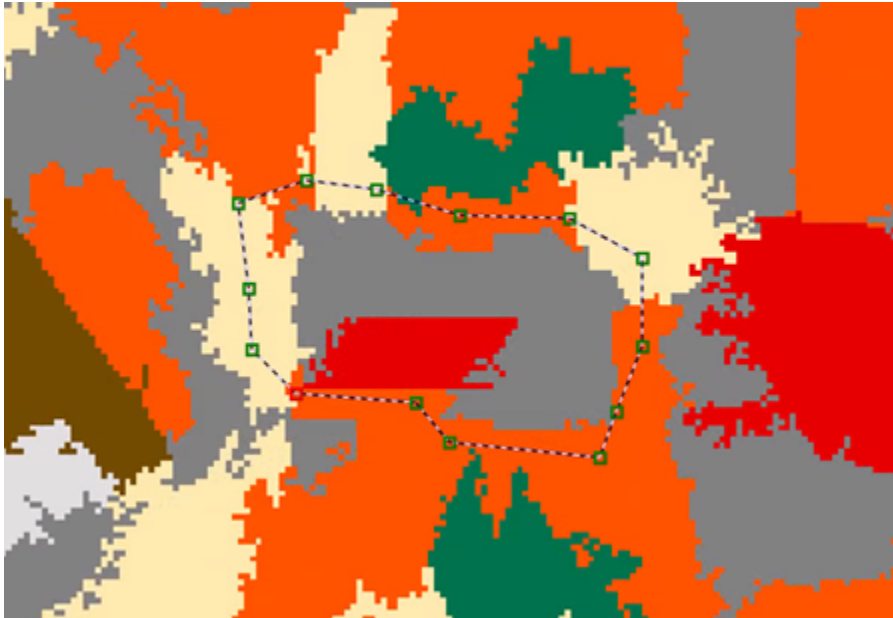


- j Double-click to finish the polygon.



The segment has been reclassified based on the specified class changes.

- k** From the Pixel Editor tab, in the Edit group, update Current Class to Roads and New Class to Buildings.
- l** Find the misclassified road and buildingDebris area, and then reclassify the area as Building.



- m** Change the transparency of the FinalParadiseClassified.tif layer to **35%**.

Hint: The transparency setting is found on the Raster Layer tab.

- n** In the Contents pane, turn off the SMS_165_10_200.tif layer, if necessary.



The misclassified buildingDebris area is visible when the classified layer is transparent. A section of the building is still misclassified as buildingDebris and should be reclassified as Building.

- o Using the skills that you just learned, reclassify some of the remaining misclassified areas.

Now that you have learned how to reclassify misclassified areas, you are ready to save the results.



In your own work, you would continue to reclassify problematic areas within the classified thematic raster, but for this exercise, you will move on to the next step in the workflow.

- p From the Pixel Editor tab, in the Save group, click Save As New.
- q In the Export Raster pane, specify an Output Raster Dataset of C:\EsriTraining\IMAD\Imagery\UnitedStates\Paradise\FinalParadiseClassifiedRC.tif.
- r Accept the remaining defaults and click Export.
- s Close the Export Raster pane.
- t Close Pixel Editor, and if a Pixel Editor window appears, click Yes.

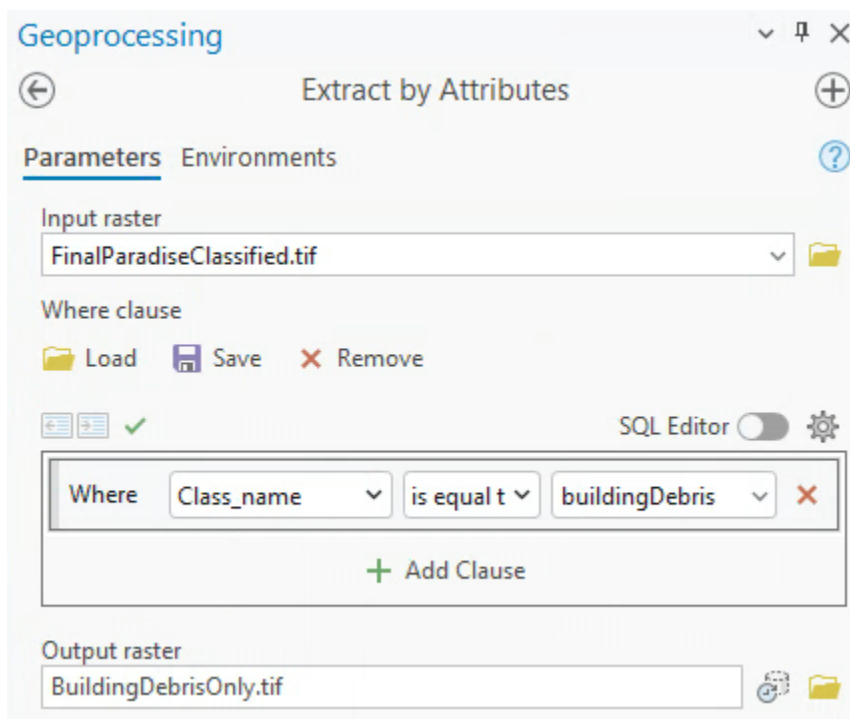
Next, you will create a derived raster with just the building debris.

Step 9: Extract the target class

In this step, you will extract the buildingDebris class from the classified thematic raster. You can then use the class for further analysis.

- a In the Contents pane, right-click the FinalParadiseClassifiedRC.tif layer and choose Zoom to Layer.
- b Enable the Geoprocessing pane, click the Back button , and search for **extract attribute**.
- c Open the Extract By Attributes (Spatial Analyst Tools) tool.
- d For Input Raster, choose FinalParadiseClassifiedRC.tif.
- e Under Where Clause, in the expression area, create the following clause: `Where Class_Name Is Equal To buildingDebris.`

- f For Output Raster, browse to `..\EsriTraining\IMAD\Imagery\UnitedStates\Paradise` and save the file as **BuildingDebrisOnly.tif**.



- g Click Run.

- h** In the Contents pane, turn off all the layers except for the BuildingDebrisOnly.tif and ParadiseRecovery50.tif layers.



Most of the building debris has been found. In a few spots, there appears to be some missed debris. Mostly, the buildingDebris class represents the actual building debris very well.

Now you have created a classified thematic raster that indicates the burned debris areas that will need to be cleaned up before the properties can be rebuilt.

- i** From the View tab, click Pane Sets and choose Mapping.

This action will keep the Contents and Catalog panes open while closing all other panes.

- j** Save your project and exit ArcGIS Pro.

Using image classification

Image classification provides additional insight into your operational environment. It can also fill in knowledge gaps about an area, especially when no other information is available. Sometimes, time and mission constraints may limit the types of image classification that you can perform. Other times, availability of images, currency of intelligence, or the type of intelligence question being asked can influence how much or how well you can perform an image classification.

In an area of limited data availability, what are the benefits of performing an image classification for a cross-country mobility analysis?

Lesson review

1. How does a training sample with mixed features (for example, two types of pavement) affect classification results?

2. What differentiates an unsupervised pixel-based classification workflow from a supervised object-based workflow?

Answers to lesson 6 questions

Exercise 6: Perform a supervised object-based classification (page 6-3)

1. What types of burn damage are visible in the training area?

Building debris and scorched land are visible.

2. What are some classes that you could include in your schema?

Answers may vary but could include Building debris, Scorched and burned land, Asphalt, Concrete, Trees, Buildings, and Barren.

Using image classification (page 6-20)

In an area of limited data availability, what are the benefits of performing an image classification for a cross-country mobility analysis?

Answers will vary, but possible responses include the following:

- An image classification can give you thematic information, such as land cover, that you otherwise do not have.
- An image classification derived from current, or updated, imagery can provide newer information on land cover that may have changed since the previous data update.
- A new image classification can be compared with existing land cover, if available, to perform a qualitative change detection.
- If applicable to the AOR, image classifications derived from images collected during different times of the year (seasons) could show a different GO/NO GO/SLOW GO result based on changing environmental conditions.

SAR imagery is a distinctive source of data that provides an invaluable resource for mission planning and analytical support. In ArcGIS Pro, you can visualize, process, and analyze data from many different types of SAR sensors.

Topics covered

 SAR collection SAR processing

What is SAR?

Synthetic aperture radar (SAR) is a type of imagery that is collected by an active remote sensor. A SAR sensor transmits microwave radar pulses and measures the returned wave, known as backscatter. This functionality differs from passive sensors, which record reflected solar energy. The active sensing characteristic of a SAR sensor allows it to collect imagery by day or by night.

Synthetic aperture and spatial resolution

Another characteristic of SAR imagery is its high spatial resolution. As a SAR sensor moves along its flight path, it combines the returns of the transmitted active radar pulses. This functionality enables a sensor with a relatively short antenna (that is, a small aperture) to synthetically elongate the antenna, increasing the aperture size and resulting in a higher spatial resolution.

Capabilities

The imagery that you have used in this course is collected in the visible and infrared portions of the electromagnetic spectrum; SAR is collected in the microwave portion of the spectrum. The longer wavelengths of radar, often measured in centimeters, enable penetration of clouds, fog, dust, or smoke. Different wavelength bands can even penetrate materials such as soil, snow, ice, or vegetation. This capability does not mean that SAR can see through objects; the microwave wavelengths are simply able to travel further before scattering and returning to the sensor. Certain material states, such as density or a high moisture content, limit the penetration depth.

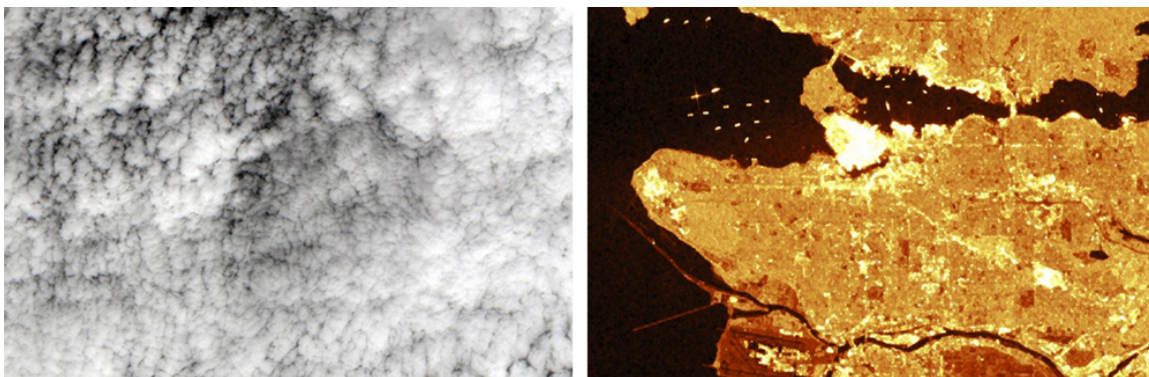


Figure 7.1. On the left, a Sentinel-2C multispectral image of Vancouver, Canada shows the city obscured by 80% cloud cover. On the right, a Sentinel-1 RTC SAR image of Vancouver, Canada, collected on the same day, shows a cloud-free landscape. (Data source: ESA, European Commission)

What is SAR? (continued)

Different material penetration capabilities are associated with SAR collection in certain microwave bands, as are described in the following table.

Application	K-band	X-band	C-band	S-band	L-band	P-band
Wavelength (cm)	0.75 to 2.4	2.4 to 3.75	3.75 to 7.5	7.5 to 15	15 to 30	30 to 100
Penetration						
Low to moderate crop canopy			X	X		
High crop canopy					X	X
Hydrometeors or rain core				X	X	X
Precipitation			X	X	X	X
Cloud, fog, dust, smog, or smoke		X	X	X	X	X
Dry alluvium		X	X	X	X	X
Dry snow or ice		X	X	X	X	X
Wet soil		X	X	X	X	X

What is SAR? (continued)

Various mapping applications, possible with SAR collection in certain microwave bands, are described in the following table.

Application	K-band	X-band	C-band	S-band	L-band	P-band
Wavelength (cm)	0.75 to 2.4	2.4 to 3.75	3.75 to 7.5	7.5 to 15	15 to 30	30 to 100
Mapping						
Canopy	X	X				
Flooded grass	X	X	X			
Flooded vegetation				X		
Flooded canopy					X	X
Earth surface	X	X	X	X	X	X
Flood	X	X	X	X	X	X
Oil spill	X	X	X	X	X	X
Sea ice	X	X	X	X	X	X
Soil moisture	X	X	X	X	X	X

Collecting SAR data

SAR imagery is collected by various platforms, such as satellites, aircraft, unmanned aerial vehicles (UAV), and even ground-based systems. While this lesson focuses on satellite collection, the basic SAR collection principles are consistent across airborne and spaceborne platforms.

As the platform carrying a SAR sensor, which is side-looking and oriented off-nadir, moves along its flight path, the sensor transmits microwave radar pulses to the earth's surface. The microwave wavelength propagates through the atmosphere, oscillating in a vertical or horizontal polarization, and scattering when it interacts with a feature or surface. The way that the wavelength scatters is influenced by surface or object roughness and material, as well as the geometry of the microwave wavelength.

The sensor measures the amplitude and phase of the returned backscatter signal. Phase determines the timing of the return, while amplitude indicates the strength (or intensity) of the return. Amplitude in a SAR image is used to characterize surface roughness, moisture, and other properties, as well as to detect features. A SAR image is typically delivered as one of two product types: ground range detected (GRD), where the pixel value represents the amplitude, and single look complex (SLC), where the pixel value represents the amplitude and phase.

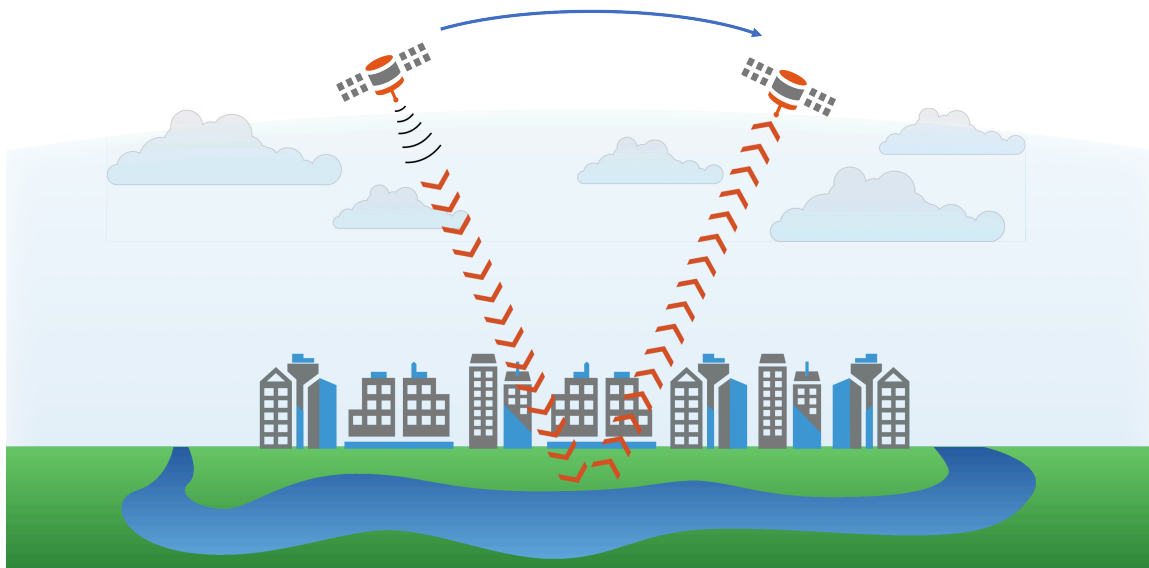


Figure 7.2. A SAR sensor typically transmits several thousand radar pulses per second and collects the return from those pulses as it moves along its orbit.

Collecting SAR data (continued)

Polarization

Active sensors like SAR can control the polarization of the transmitted microwave signal. The received polarization is dependent on the interaction between the microwave signal and an object. SAR images may contain multiple polarizations, which can highlight different features.

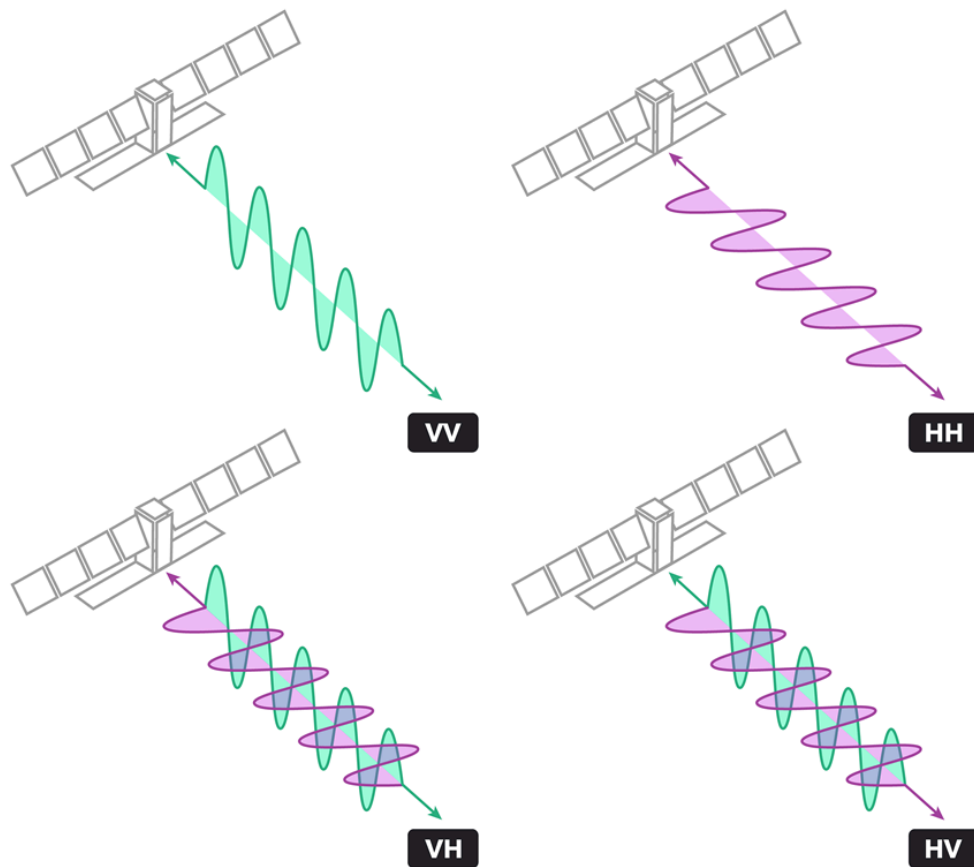


Figure 7.3. A sensor can transmit and receive vertically polarized waves (VV), transmit and receive horizontally polarized waves (HH), transmit vertically polarized waves and receive horizontally polarized waves (VH), or transmit horizontally polarized waves and receive vertically polarized waves (HV).

SAR use cases

There are several methods for analyzing SAR imagery data that differ from other image analysis techniques. For instance, combining SAR data from different dates into a layered display can help reveal landscapes and features which might otherwise be hidden. In the first image (on the left), combined differences in SAR backscatter intensity values over time reveal the extent of riverine flooding in Madagascar. Using multiple SAR collects, the second image (in the middle) reveals the progression of change to land cover due to flooding in the Tulare Lake Basin in California over a period of six months. The third image (on the right) shows detected ships in the Singapore Strait. These ships are visible because of clustered pixels with higher backscatter intensity are contrasted relative to the surrounding sea surface.

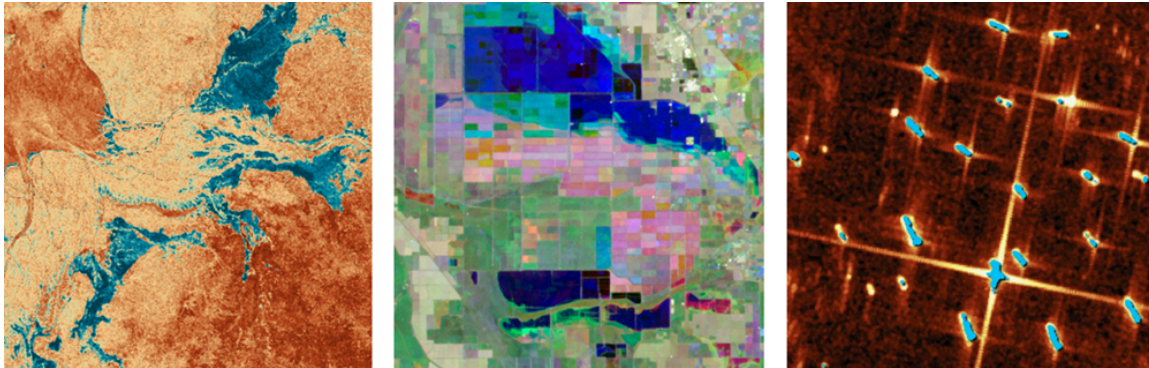


Figure 7.4. A SAR image can reveal information such as (from left to right) flooding, changes to land cover, and object detection. (Data source: ESA, European Commission)

What are some potential use cases for SAR imagery?

SAR processing

A SAR image is non-literal, meaning that it is not a direct visual representation of features on the ground. Instead, it represents the measured radar backscatter intensity, which is influenced by scattering mechanisms and collection geometry. As a result, features may appear distorted or artificially bright. Interpretation of a SAR image requires understanding of these radiometric and geometric effects as well as mitigation techniques to use when processing a SAR image for analysis.

Some of these complexities and their mitigation techniques are described in the following table.

Issue	Description	Mitigation technique
Orbit drift	Inaccuracies in a satellite's orbital information	Apply orbit correction
Thermal noise	Backscatter disturbances caused by electron motions in the satellite circuitry	Thermal noise removal
Uncalibrated digital numbers	Initial reflectivity values are not meaningful	Apply radiometric calibration to convert values to normalized backscatter
Radiometric distortions due to topography	Features facing towards the sensor are artificially brighter; features facing away are artificially darker	Radiometric terrain flattening to normalize backscatter values



ArcGIS Pro Help: Sensor support for synthetic aperture radar sensors

SAR workflow

There are different methods of processing SAR imagery data depending on the data format and the sensor. The workflow described in this section lists the steps to process Sentinel-1 GRD data. Though the SAR imagery data that you use may have slightly different processing requirements, the desired outcome is the same: a calibrated, terrain-corrected, analysis-ready image.



- 1. Orbit correction:** Sentinel-1 SAR data is delivered from the European Space Agency with predicted orbit state vector (OSV) information, meaning that the orbit information is based on the *planned* satellite position and velocity. Slight differences in position and velocity data can affect geolocation and other analysis processes. You can download updated approximate (Sentinel Restituted) or refined (Sentinel Precise) OSV data and apply a correction to the orbital information in the SAR data. The process is different for other SAR sensors, because the OSV information is embedded in the SAR metadata and does not need to be downloaded from an external site.
- 2. Radiometric calibration:** Radiometric calibration converts SAR pixel values into physically meaningful measures of radar backscatter. This process produces backscatter coefficients, such as beta nought (β^0), that can be directly related to the physical properties of features in the image. Additional radiometric corrections, such as thermal noise removal, may be applied to reduce sensor-related noise in the data. Subsequent processing, including radiometric terrain flattening, further adjusts the calibrated backscatter to account for terrain effects and viewing geometry to improve comparability across varying surface orientations and slopes.
- 3. Speckle filtering:** Speckle in a SAR image appears grainy or with a salt-and-pepper effect. This speckling is the result of coherent illumination, or effects from small scattering waves. Not all SAR images should be despeckled. For instance, despeckling is not recommended for ship detection analysis, because it can reduce the intensity of bright objects on the water.
- 4. Geometric terrain correction:** This process orthorectifies the SAR data, correcting geometric distortions, and correctly geolocating the imagery.

SAR workflow (continued)

5. **Analysis:** In ArcGIS Pro, you can use SAR data for various types of analysis, including oil spill identification, ship detection, and creating color composite images. The analysis that you plan to perform with the SAR data can influence the way that you process the data. In some cases, analysis might require small deviations from the standard processing workflow. For instance, an analysis tool could be applied before all processing steps are complete. However, it is very important to understand how each step in the process affects the underlying SAR data.

Exercise 7

Detect ships using SAR data

Imagine that you are working on a joint North Atlantic Treaty Organization (NATO) intelligence operation to locate merchant-flagged vessels suspected of smuggling weapons. The vessels are known to transit the Strait of Gibraltar, turn off their automated identification system (AIS), and meet up with smaller vessels to offload the illicit cargo.

Your task is to use SAR data to locate vessels transiting the strait into the Mediterranean Sea. You have obtained partially processed Sentinel-1 GRD SAR data. You will complete the rest of the processing sequence and run analysis to detect bright objects on the sea surface. Your colleagues will compare the results of this analysis to gaps in AIS information from the same time.

In this exercise, you will perform the following tasks:

- Process SAR data.
- Detect bright ocean objects.

Step 1: Apply radiometric terrain flattening

SAR data must be processed before use in analysis workflows. A colleague downloaded the Sentinel-1 SAR data a few days ago and already started processing it. Your colleague applied orbit correction, removed thermal noise, and applied radiometric calibration.

In this step, you will continue processing the data to apply radiometric terrain flattening. This process will correct the backscatter values for radiometric distortions due to topography. Normally, if you were only going to use the SAR data to detect vessels on the water, this step would not be necessary, because water is not affected by terrain distortions. However, after you have detected vessels on the open water and your colleague has compared the results to AIS, you plan to run further analysis closer to the coast, especially in sheltered coves where the illicit cargo might be initially transferred from land to the rendezvous vessels. For that stage of the analysis, the radiometrically terrain flattened data will be important.

- a Start ArcGIS Pro, and then click Open Another Project.
- b Browse to **C:\EsriTraining\IMAD\Projects\Gibraltar_SAR** and open the Gibraltar_SAR project.
- c In the Catalog pane, expand the Gibraltar folder, and then add S1C_IW_GRD_OC_TNR_CALB0.crf to the map.

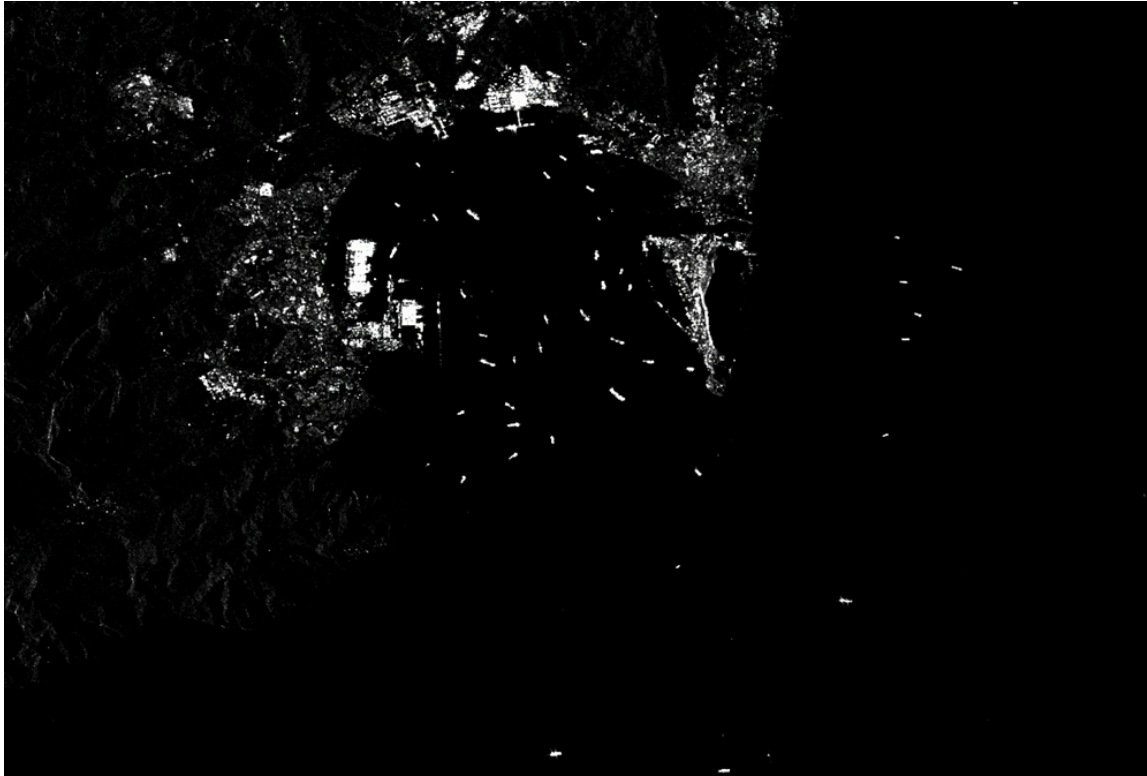
The file name refers to the image type and the processing lineage:

- S1C: Sentinel-1C satellite
- IW: Interferometric Wide swath mode collection
- GRD: Ground Range Detected
- OC: (Processing step) Orbit corrected
- TNR: (Processing step) Thermal noise removed
- CALB0: (Processing step) Backscatter values calibrated to beta nought (β^0)

As you apply additional processing steps, the output file names will reflect the updated lineage. In your workflow, you will slightly modify the output file name to decrease its length.

- d Zoom to the Bay of Gibraltar bookmark.

Hint: Map tab > Navigate group > Bookmarks



- e Use the Swipe tool to compare the SAR image to the basemap.

You can make out some features, which appear to be buildings and vessels. However, the brightness values are artificially darker in some areas and brighter in others due to distortions caused by the topography. You can mitigate this issue by applying radiometric terrain flattening. First, you will examine the layer properties.

- f In the Contents pane, open the Properties for the S1C_IW_GRD_OC_TNR_CALB0.crf layer.
- g In the Layer Properties window, click Source and expand Processing History.

1. What processing has already been applied to this data?



Though it is a good practice to name SAR input and output files with a designation that reflects its origin and processing lineage, that does not always happen. The best way to determine which processing has been applied to the SAR radar data is to view the processing history.

h Expand Radiometric Calibration.

This data was radiometrically calibrated to beta nought, which is a SAR backscatter coefficient representing radar reflectivity per unit area in slant-range geometry. It describes the radar brightness returned to the sensor before normalization for terrain or incidence-angle effects. Calibration to beta nought is a requirement for input to the Apply Radiometric Terrain Flattening tool.

i Expand Band Metadata.

The source data is dual VV/VH polarized. When correcting for thermal noise and calibrating the reflectivity values, you have the option of selecting one or both bands for correction.

2. Which polarization band has been corrected?

j Expand Raster Metadata.

3. When was this image collected?

You know that the vessels suspected of weapons smuggling arrive at the rendezvous location just after sunset, so this particular image is appropriate for your analysis.

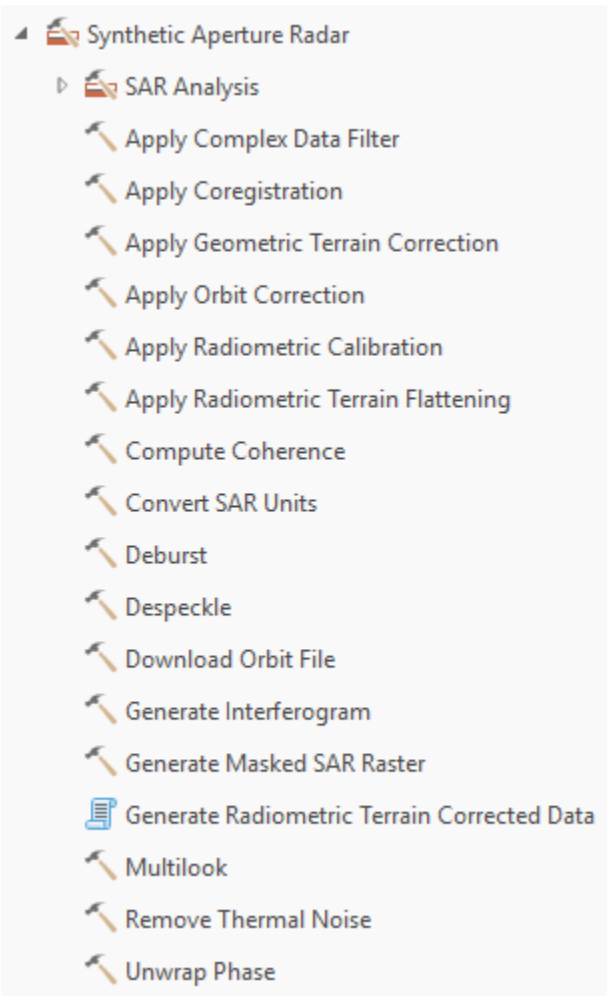
You will now apply radiometric terrain flattening to your SAR data.

k Close the Layer Properties.

l From the Analysis tab and the Geoprocessing group, click Tools.

m In the Geoprocessing pane, click Toolboxes.

- n Expand Image Analyst Tools and Synthetic Aperture Radar.



- o Open the Apply Radiometric Terrain Flattening tool and specify the following parameters:

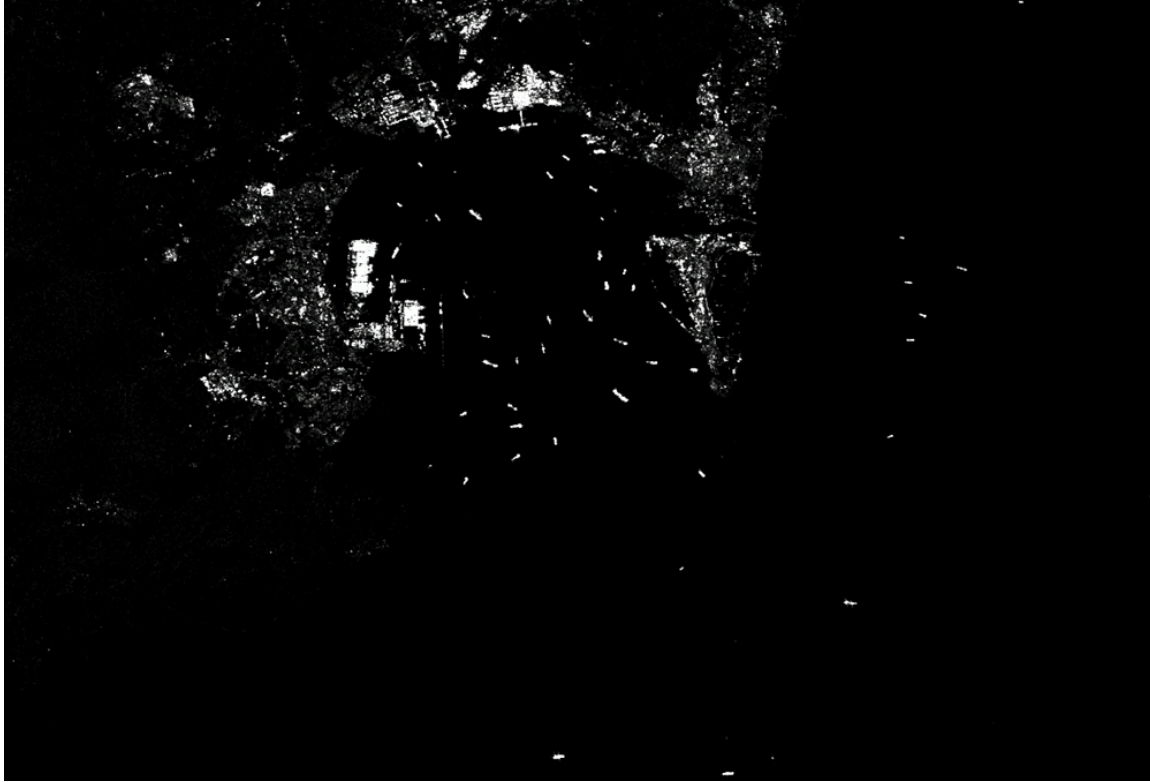
- Input Radar Data: Browse to **..\EsriTraining\IMAD\Imagery\Gibraltar\S1C_IW_GRD_OC_TNR_CALB0.crf**
- Output Radar Data: Browse to **..\EsriTraining\IMAD\Imagery\Gibraltar**, and then for Name, enter **S1C_IW_GRD_RTFG0.crf**
- DEM Raster: Choose Gibraltar_DEM.tif from the drop-down.
- Calibration Type: Confirm that Gamma Nought is selected.

Gamma nought (γ^0) refers to the way that the beta nought backscatter values are normalized with the DEM. This selection is required in order to use the analysis tool in your workflow, because it optimizes object detection.

- p** Keep the remaining defaults and click Run.



It will take a few minutes for the tool to run.



- q** Use the Swipe tool to compare the radiometric terrain corrected and terrain flattened layers.

There are subtle visible differences between the two images, but more importantly, the backscatter values are now normalized to account for terrain effects.

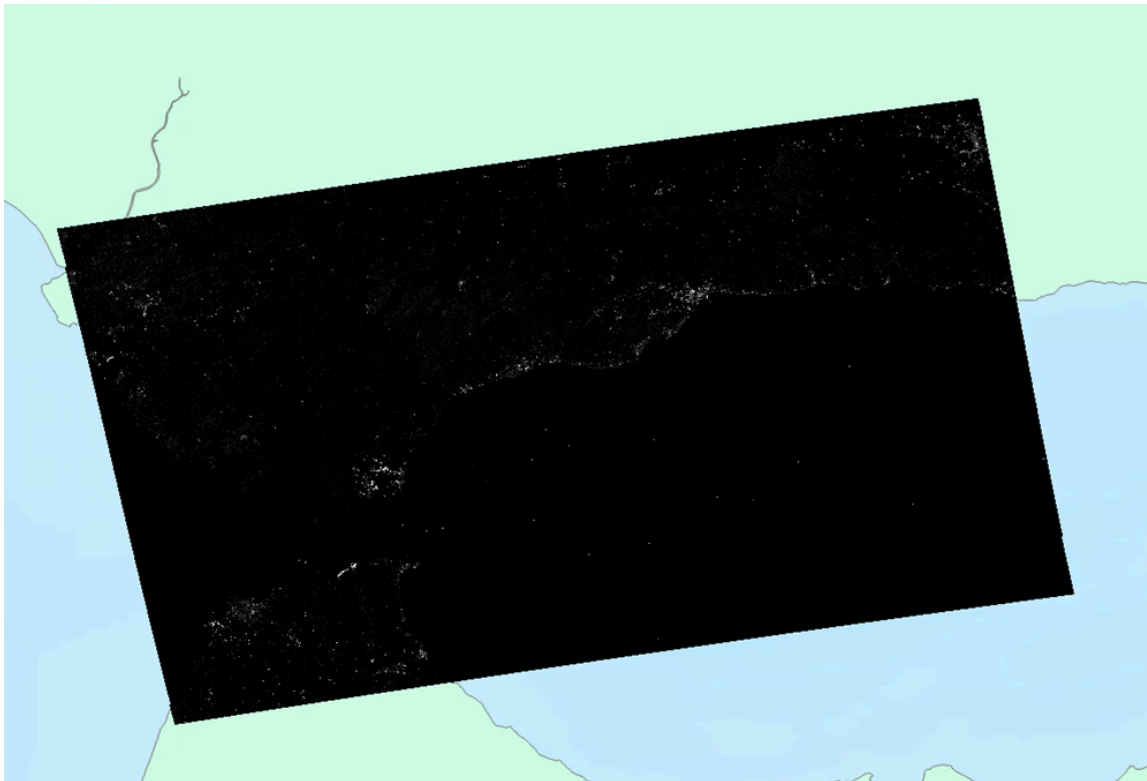
- r** Save your project.

Step 2: Detect bright ocean objects

You will now use an analysis tool, Detect Bright Ocean Objects, to find vessels in the Mediterranean Sea, near the Strait of Gibraltar. Detect Bright Ocean Objects clusters and filters pixels to detect bright human-made objects. This tool requires SAR radar data that is calibrated to gamma nought.

You will finish processing the SAR data after running the analysis tool; applying other processes such as despeckle or geometric terrain correction will change the way that the pixels are distributed and could affect the detection of objects.

- a From the Contents pane, zoom to the full extent of the S1C_IW_GRD_RTFG0.crf layer.
- b Still in the Contents pane, turn on the Land layer.



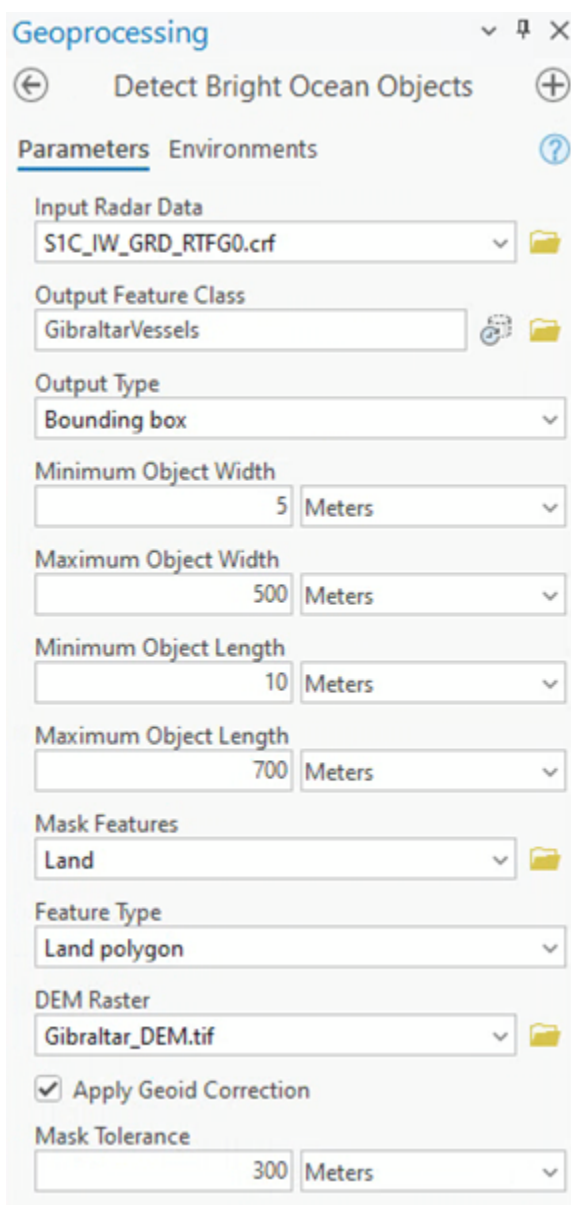
The Land layer will be used in the geoprocessing tool to mask SAR data outside the layer from detection.

- c Turn off the Land layer.
- d In the Geoprocessing pane, click the Back button.
- e In the Synthetic Aperture Radar toolbox, expand the SAR Analysis toolbox.

f Open the Detect Bright Ocean Objects tool and specify the following parameters:

- Input Radar Data: Browse to **..\EsriTraining\IMAD\Imagery\Gibraltar\S1C_IW_GRD_RTFG0.crf**.
- Output Feature Class: Browse to **..\EsriTraining\IMAD\Projects\Gibraltar_SAR\Gibraltar_SAR.gdb**, and then for Name, enter **GibraltarVessels**.
- Output Type: Bounding Box
- Minimum Object Width: **5** Meters
- Maximum Object Width: **500** Meters
- Minimum Object Length: **10** Meters
- Maximum Object Length: **700** Meters
- Mask Features: Land
- Feature Type: Land Polygon

- DEM Raster: Gibraltar_DEM.tif
- Mask Tolerance: **300** Meters



The screenshot shows the 'Detect Bright Ocean Objects' tool interface. The 'Parameters' tab is active. The 'Input Radar Data' is set to 'S1C_IW_GRD_RTFG0.crf'. The 'Output Feature Class' is 'GibraltarVessels'. The 'Output Type' is 'Bounding box'. The 'Minimum Object Width' is 5 Meters, 'Maximum Object Width' is 500 Meters, 'Minimum Object Length' is 10 Meters, and 'Maximum Object Length' is 700 Meters. The 'Mask Features' is 'Land' and the 'Feature Type' is 'Land polygon'. The 'DEM Raster' is 'Gibraltar_DEM.tif'. The 'Apply Geoid Correction' checkbox is checked. The 'Mask Tolerance' is 300 Meters.

Geoprocessing

Detect Bright Ocean Objects

Parameters Environments

Input Radar Data
S1C_IW_GRD_RTFG0.crf

Output Feature Class
GibraltarVessels

Output Type
Bounding box

Minimum Object Width
5 Meters

Maximum Object Width
500 Meters

Minimum Object Length
10 Meters

Maximum Object Length
700 Meters

Mask Features
Land

Feature Type
Land polygon

DEM Raster
Gibraltar_DEM.tif

☒ Apply Geoid Correction

Mask Tolerance
300 Meters

You are searching for the cargo ship, as well as the small boat which will transfer the weapons, so you entered object search parameters that will enable detection of both small and large vessels.

9 Click Run.

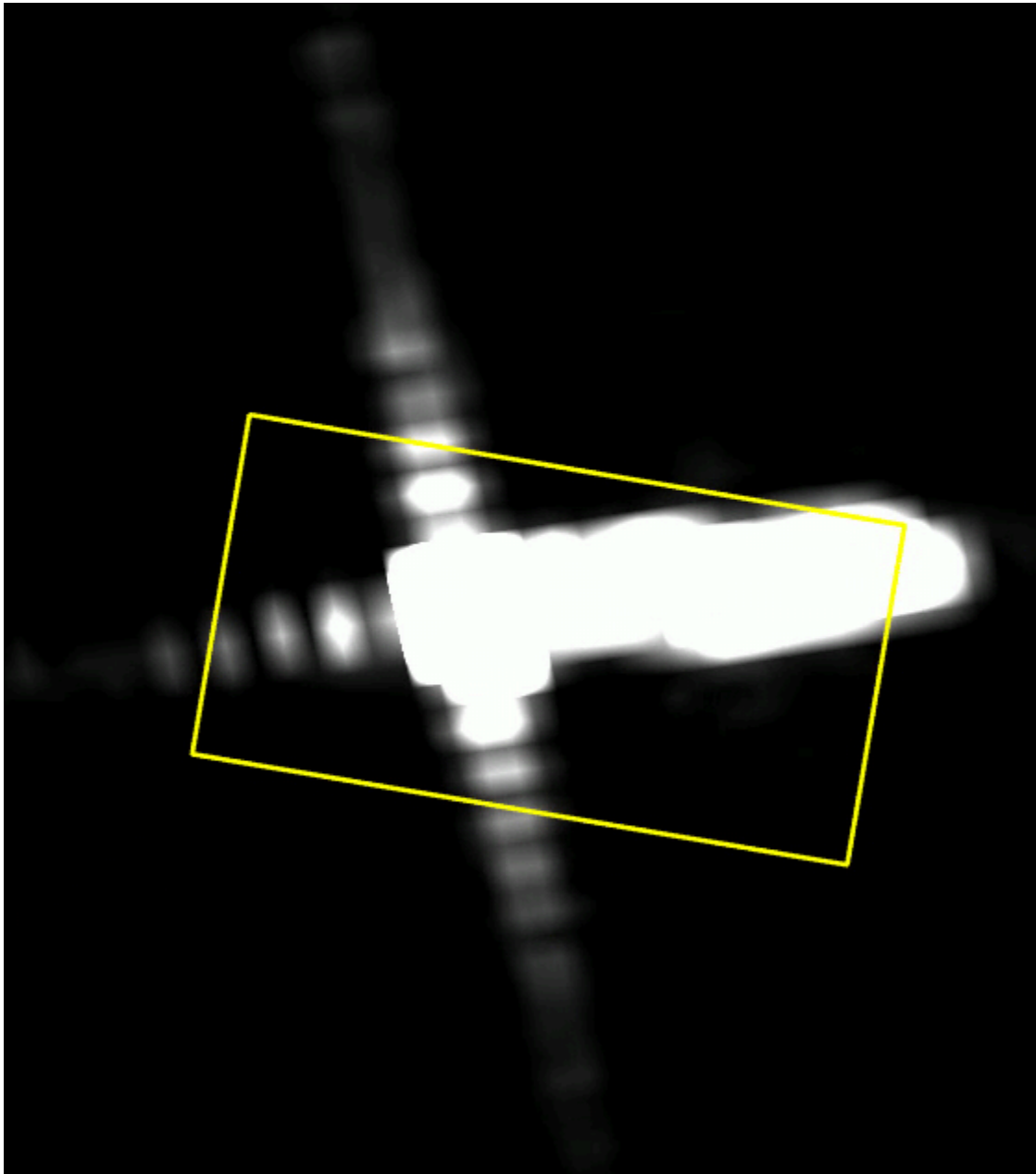


It will take several minutes for the tool to run.

- h** In the Contents pane, change the symbology of the GibraltarVessels layer to a no-color fill with a 2-point yellow outline.
- i** Still in the Contents pane, turn off the visibility of all the layers *except* the following:

 - GibraltarVessels
 - S1C_IW_GRD_RTFG0.crf
 - Any basemap layers

j Zoom to the Detected Object bookmark.



Bright clusters of objects on the water have been identified as potential human-made objects, such as vessels, oil rigs, and offshore wind turbines. The radiating lines are an artifact of SAR imaging.

4. What do you notice about the relationship between the bright object and the polygon around it?

The Detect Bright Ocean Objects tool used the input DEM to orthorectify the output, but the SAR radar data itself is not yet orthorectified.

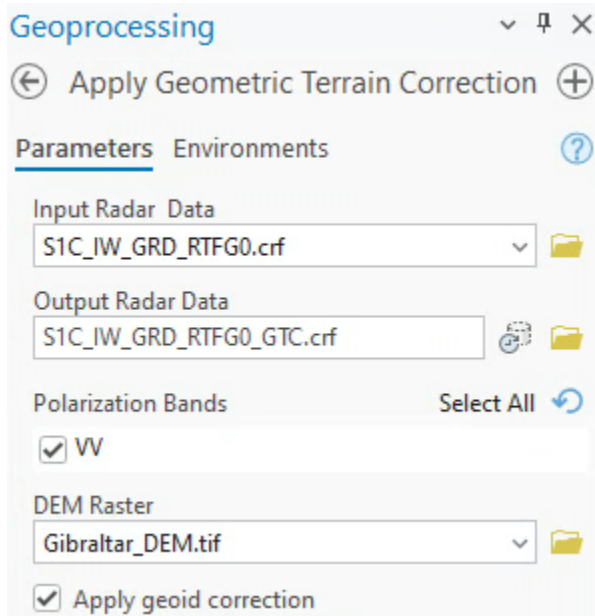
Step 3: Apply geometric terrain correction

Now that you have detected bright objects on the water, you will orthorectify the SAR radar data using the Apply Geometric Terrain Correction tool. Although the Despeckle tool is normally run before applying geometric terrain correction, you will omit it from the workflow; this analysis is focused over water and does not require speckle reduction.

- a In the Geoprocessing pane, click the Back button.

b From the Synthetic Aperture Radar toolset, open the Apply Geometric Terrain Correction tool, and specify the following parameters:

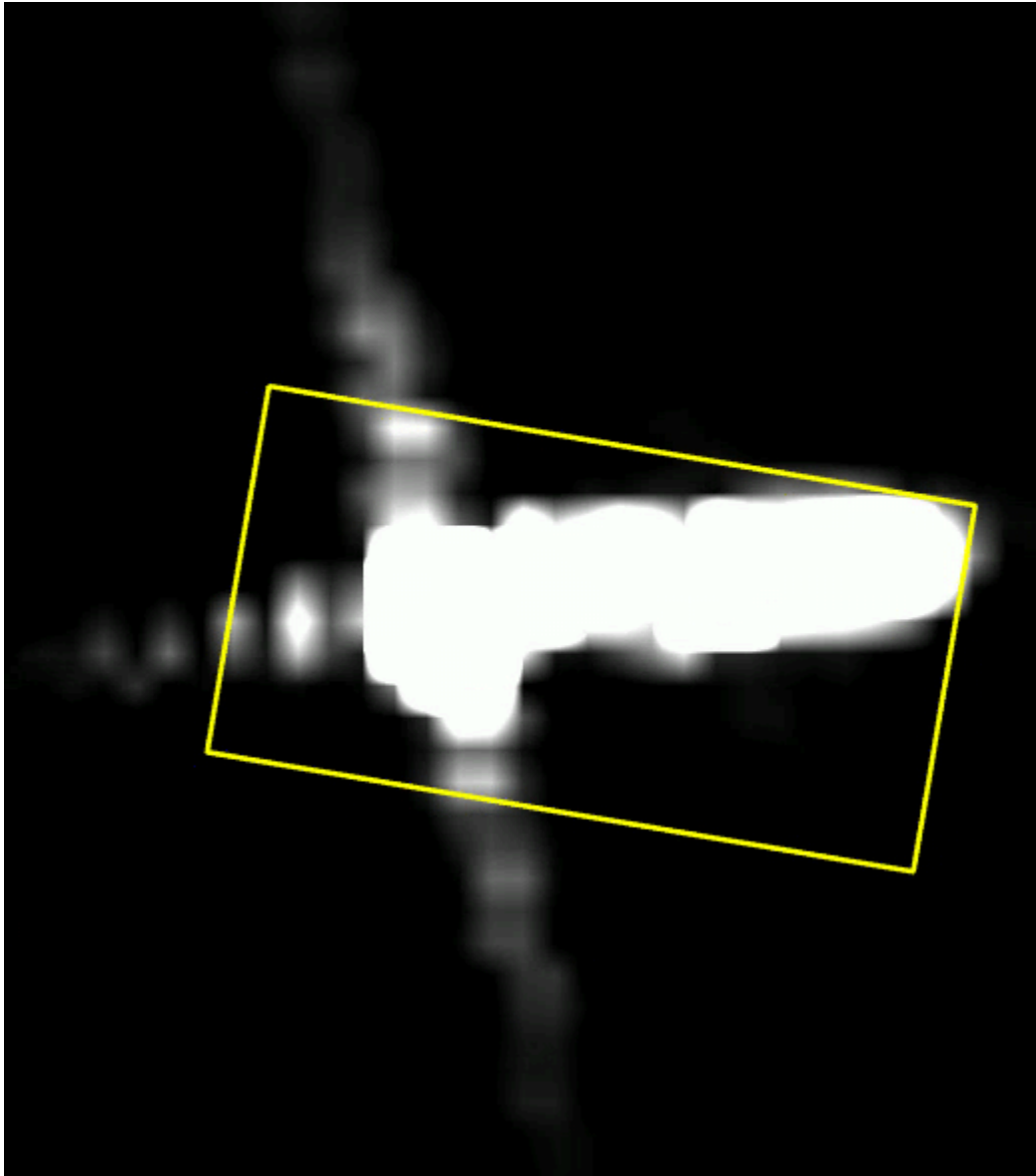
- Input Radar Data: Browse to **..\EsriTraining\IMAD\Imagery\Gibraltar\S1C_IW_GRD_RTFG0.crf**.
- Output Radar Data: Browse to **..\EsriTraining\IMAD\Imagery\Gibraltar**, and then for Name, enter **S1C_IW_GRD_RTFG0_GTC.crf**.
- DEM Raster: Gibraltar_DEM.tif



c Keep the remaining defaults and click Run.



It will take several minutes for the tool to run.



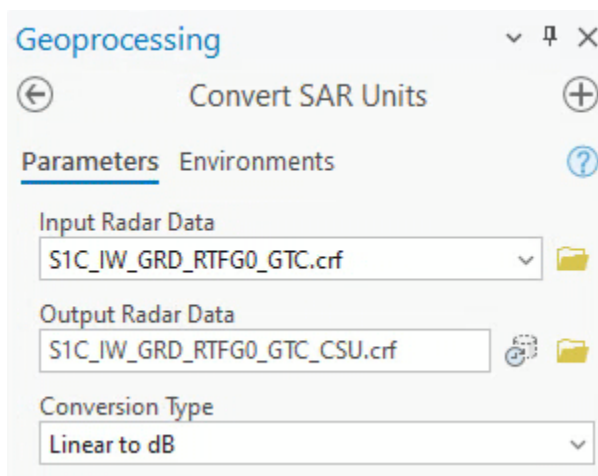
You have orthorectified the SAR radar data. The discrepancy between the bright pixels and the yellow object detection polygons has been resolved.

Step 4: Convert SAR units

You have completed the processing steps for using Sentinel-1 GRD SAR radar data and have analyzed the data to detect potential vessels on the Mediterranean Sea. Before you pass the analysis results to your colleagues, you will convert the SAR data units to decibels (dB). This step

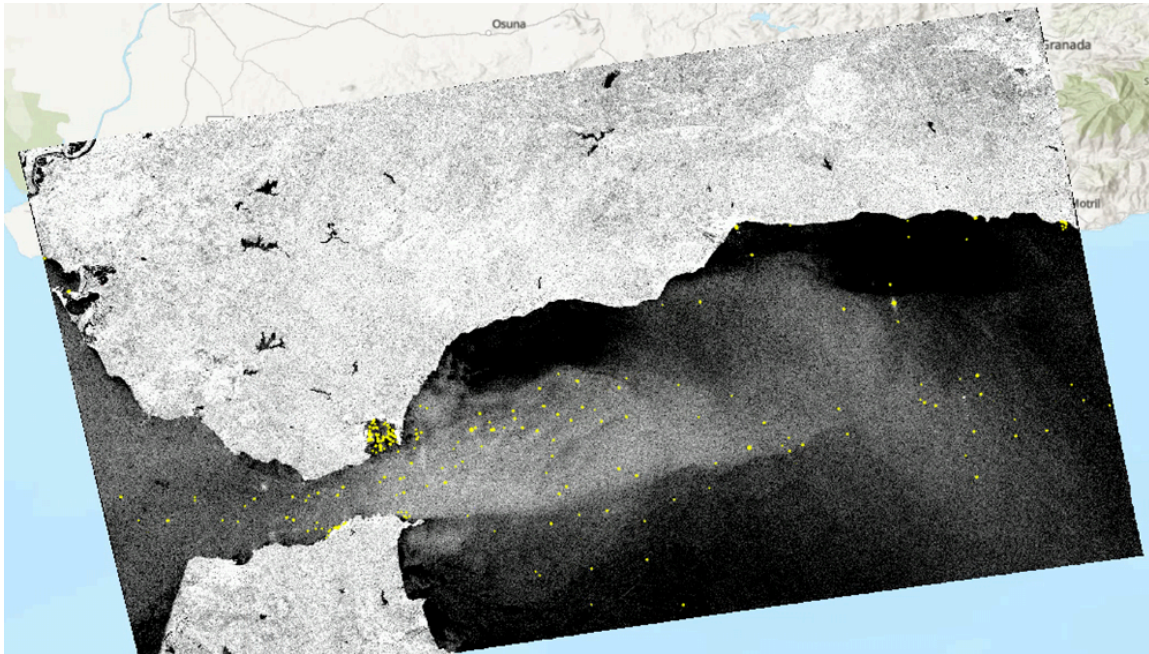
will reduce the dynamic range of values. Although not necessary for processing or further analysis, it will improve image display and interpretation.

- a In the Geoprocessing pane, click the Back button.
- b From the Synthetic Aperture Radar toolset, open the Convert SAR Units tool, and specify the following parameters:
 - Input Radar Data: Browse to **..\EsriTraining\IMAD\Imagery\Gibraltar**
S1C_IW_GRD_RTFG0_GTC.crf
 - Output Radar Data: Browse to **..\EsriTraining\IMAD\Imagery\Gibraltar**, and then for Name, enter **S1C_IW_GRD_RTFG0_GTC_CSU.crf**
 - Conversion Type: Linear to dB



- c Click Run.

- d From the Contents pane, zoom to the extent of the new layer.



It is now easier to visually interpret the sea state, including wind-generated surface roughness, which produces high backscatter and appears brighter.

You could process the SAR radar data again, this time with the VH polarization band. The VH polarization band will highlight different features and may provide more insight into the movement of the small vessel. However, for the purpose of this exercise, you have completed your task.

- e Save your project and exit ArcGIS Pro.

Lesson review

1. Describe the difference between active and passive remote sensing.

2. Which processing step is used to orthorectify a SAR image?
 - a. Radiometric calibration
 - b. Geometric terrain correction
 - c. Radiometric terrain flattening
 - d. Thermal noise removal

Answers to lesson 7 questions

Exercise 7: Detect ships using SAR data (page 7-11)

1. What processing has already been applied to this data?

Apply Orbit Correction, Thermal Noise Removal, and Radiometric Calibration

2. Which polarization band has been corrected?

The VV polarization band has been corrected. This polarization band is recommended for use with vessel detection analysis.

3. When was this image collected?

This image was collected on November 23, 2025 at 6:17 PM.

4. What do you notice about the relationship between the bright object and the polygon around it?

There is a discrepancy with the alignment of the bright object and the yellow polygon.

Motion imagery, referred to in ArcGIS Pro as geospatial video, is an invaluable resource on the battlefield. Whether it is used to provide force protection overwatch for troops on the ground or gather real-time information on hostile targets, it plays an important role in ensuring mission success. In this lesson, you will learn how to use ArcGIS Pro to visualize and analyze geospatial video.

Topics covered

- Motion Imagery Standards Board metadata

- Analyzing geospatial video

Uses of motion imagery

Motion imagery is a distinctive category of imagery and provides the warfighter with a unique view of their operational environment.

How would you incorporate motion imagery into your work to help with situational awareness?

Motion imagery in ArcGIS Pro

ArcGIS Image Analyst provides functionality for playing and analyzing video data that is motion-imagery compliant. To achieve motion-imagery compliance, a single video file must contain a video stream and associated metadata that makes the video geospatially aware. To be used in ArcGIS Pro, motion imagery must meet certain video and metadata format criteria. When motion imagery meets this criteria, it is referred to as geospatial video.

Supported video formats

ArcGIS Image Analyst supports the following video formats:

- | | |
|--|---|
| <ul style="list-style-type: none"> • AOMedia Video 1 File (.av1) • Audio Video Interleaved (.avi) • H264 Video File (.h264) • H265 Video File (.h265) • HLS (Adaptive Bitrate [ABR]) (.m3u8) • M2TS Transport Stream (.m2ts) • MOV file (.mov) • MPEG File (.mpeg) • MPEG File (.mpg) • MPEG-2 File (.mp2) | <ul style="list-style-type: none"> • MPEG-2 File (.mpg2) • MPEG-2 Program Stream (.ps) • MPEG-2 Transport Stream (.ts) • MPEG-4 File (mpg4) • MPEG-4 Movie (.mp4) • MPEG-Dash (.mpd) • VLC (mpeg2) (.mpeg2) • VLC Media File (.mpeg4) • VLC Media File (.vob) • Windows Media Video File (.wmv) |
|--|---|

Metadata requirements

You can play any motion imagery file if it is one of the accepted file formats. However, if you want to use the functionality in ArcGIS Pro, the file must meet certain metadata requirements as put forward by the Motion Imagery Standards Board (MISB).

The MISB formulates, reviews, and recommends standards for motion imagery metadata for the Department of Defense (DoD), Intelligence Community (IC), and National System for Geospatial Intelligence (NSG).

Motion imagery in ArcGIS Pro (continued)

ArcGIS Pro requires that video metadata meet MISB standards. To use the full functionality of ArcGIS Image Analyst to analyze your motion imagery, the data must have, at minimum, the following 12 metadata fields:

- | | |
|---|--|
| <ul style="list-style-type: none">• Precision Time Stamp• Sensor Latitude• Sensor Longitude• Sensor Ellipsoid Height• Platform Heading Angle• Platform Pitch Angle | <ul style="list-style-type: none">• Platform Roll Angle• Sensor Relative Roll Angle• Sensor Relative Elevation Angle• Sensor Relative Azimuth Angle• Horizontal Field of View• Vertical Field of View |
|---|--|



ArcGIS Pro Help: *Introduction to geospatial video*

Geospatial video in ArcGIS Pro

ArcGIS Pro provides functionality to visualize, mark up, and export geospatial video for analysis, directly enabled by the embedded metadata. Additionally, the heads-up display (HUD) shows select information from the video metadata that can be used for analysis or situational awareness.



Figure 8.1. Examples of information displayed in a geospatial video HUD. (Data source: L3 Harris Technologies)



ArcGIS Pro Help: *Work with the geospatial video player*

Exercise 8

Use geospatial video for intelligence analysis



This scenario is completely fictitious in nature and should not be viewed as a representation of an actual prior operation.

You are an analyst working for an FBI field office in Colorado. Recent reporting has indicated that a shipment of illicit materials is being smuggled from Cheyenne, Wyoming, to the Northern Colorado Regional Airport in Loveland, Colorado.

The vehicle transporting illicit materials is reported to be a blue truck tractor towing double silver trailers, traveling south on Interstate 25 from Cheyenne.

The FBI plans to interdict the shipment at the airfield to detain the driver and whomever the driver is delivering the smuggled goods to at the airfield. They plan to station a forward lookout north of Wellington, Colorado, to notify the interdiction team that the truck is en route to the airport.

You have been tasked with identifying the speed of the truck and reporting estimated arrival times to Wellington and the airport in Loveland.

In this exercise, you will perform the following tasks:

- Determine vehicle speed.
- Determine travel time to identified locations.

Step 1: Prepare a project

When analyzing geospatial video, an important first step is to set the spatial reference system of the map that you are working in to a projected coordinate system (PCS). If the map is not set to a PCS, you will be unable to perform distance measurements. For this exercise, you will set the map's spatial reference system to a Universal Transverse Mercator (UTM) projected coordinate system.

- a Start ArcGIS Pro, and then click Open Another Project.
- b Browse to **C:\EsriTraining\IMAD\Projects\Colorado** and open the Colorado project.
- c In the Catalog pane, expand Maps and open Map.



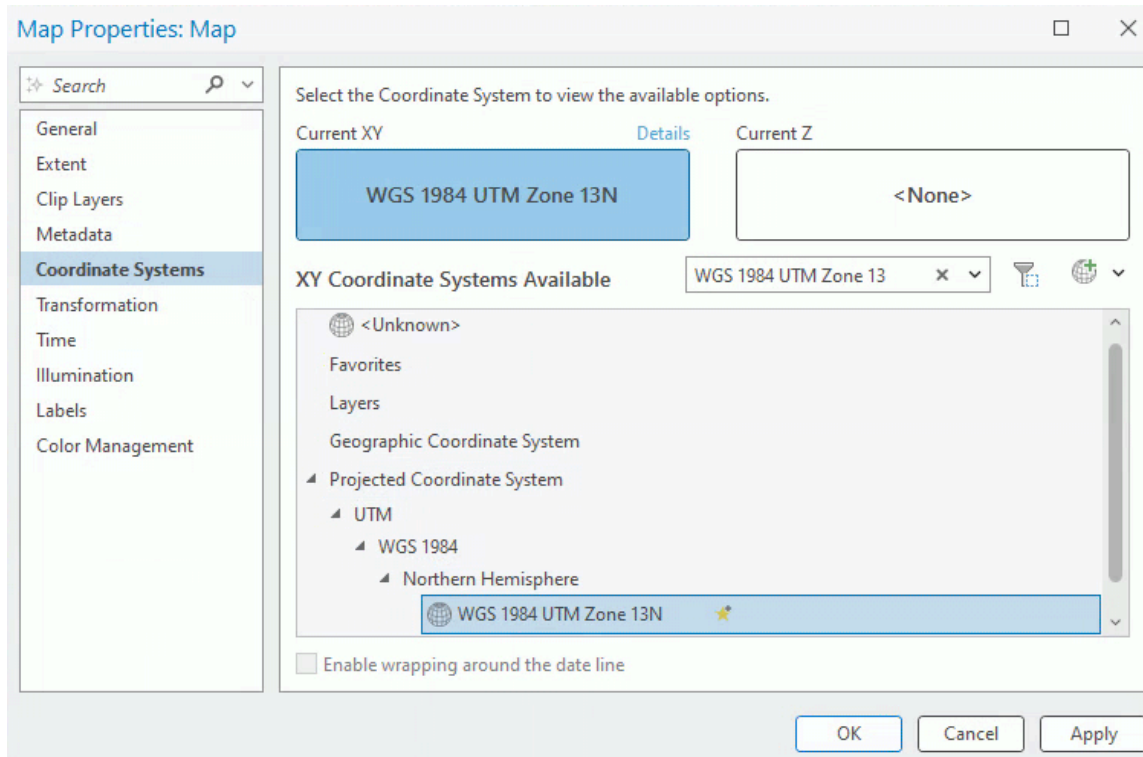
If you are working in a closed environment without internet access, open Map_Disconnected.

- d From the Map tab, in the Layer group, click Basemap and choose Imagery Hybrid.

The information in the Hybrid Reference Layer will provide more context to the imagery displayed in the basemap.

- e In the Contents pane, right-click Map and choose Properties.
- f In the Map Properties dialog box, click the Coordinate Systems tab.
- g In the XY Coordinate Systems Available search field, type **WGS 1984 UTM Zone 13** and press Enter.
- h Expand Projected Coordinate System, then expand UTM, WGS 1984, and Northern Hemisphere.

- i Click WGS 1984 UTM Zone 13N.



- j Click OK.

Your map is now set to this projected coordinate system.



If you are using Map_Disconnected, your basemap will appear differently.



If working with geospatial video in one area on a regular basis, set the default spatial reference to a projected coordinate system in the project options.

For more information, see [ArcGIS Pro Help: Map and scene options](#).

In the next step, you will add a video to your map and begin using some of the tools in the video player.

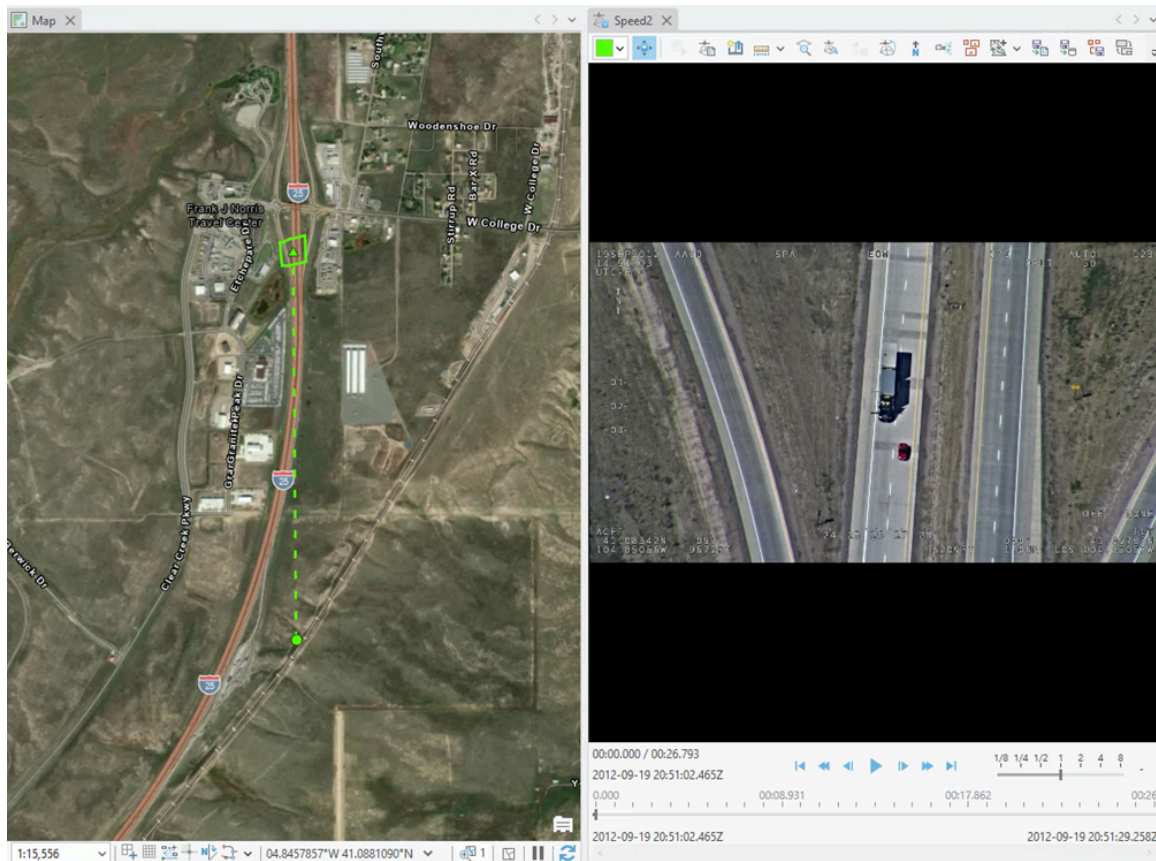
Step 2: Examine a video

To determine the approximate times that the truck will arrive at the two locations that you have been tasked to assess, you first need to identify the truck's current position and speed.

- a In the Catalog pane, expand Folders and FortCollins, and then add the Speed2.ts video to your map.

The video player opens in a floating pane. You will dock the video player to the right of the map.

- b Drag the Speed2 tab and, using the guides, dock the video to the right of the map.
- c In the video player window, click the Zoom To Video button .



Your map symbology may differ.



You can also access most video tools, such as Zoom To Video, on the Player tab.

You will change the symbology to a bright yellow color so that you can more easily identify the video file and the associated graphics.

- d** In the video player, under Speed2, click the color swatch and select a bright yellow color.

The symbology color in the Map tab updates to yellow.

1. What is the nearest major city?

Hint: You may need to zoom out in the map view.

2. What is the date and time shown on the motion imagery footage?

Hint: For a full view of the video, right-click the Speed2 video player tab and choose Move To Previous Tab Group.

3. In which direction is the truck traveling?

4. On which interstate is the truck traveling?

You have added geospatial video data to your map and identified information about the truck's current position and direction of movement.

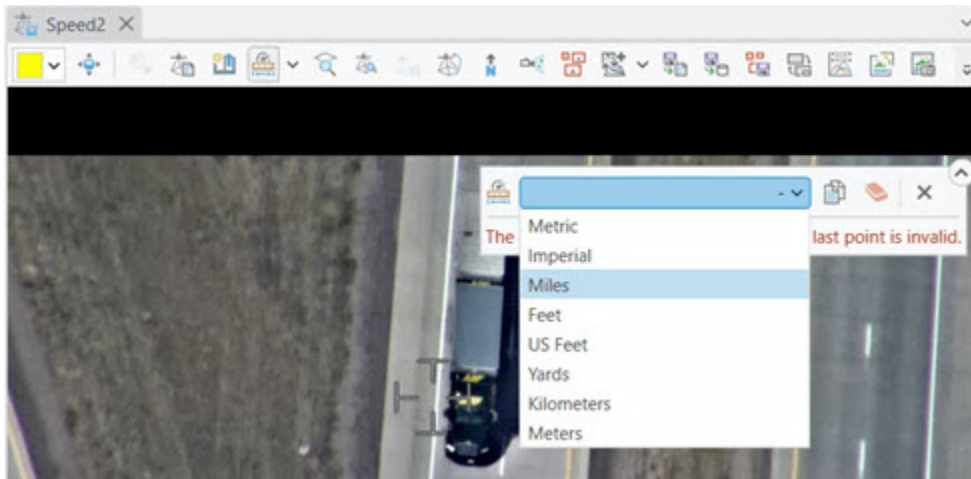
Step 3: Measure speed

Now that you have identified the truck's location and direction of travel, you will calculate the approximate speed of the truck using the Measure Speed tool.

- a** In the video player, to the right of the Measure Distance button , click the down arrow and select Measure Speed.

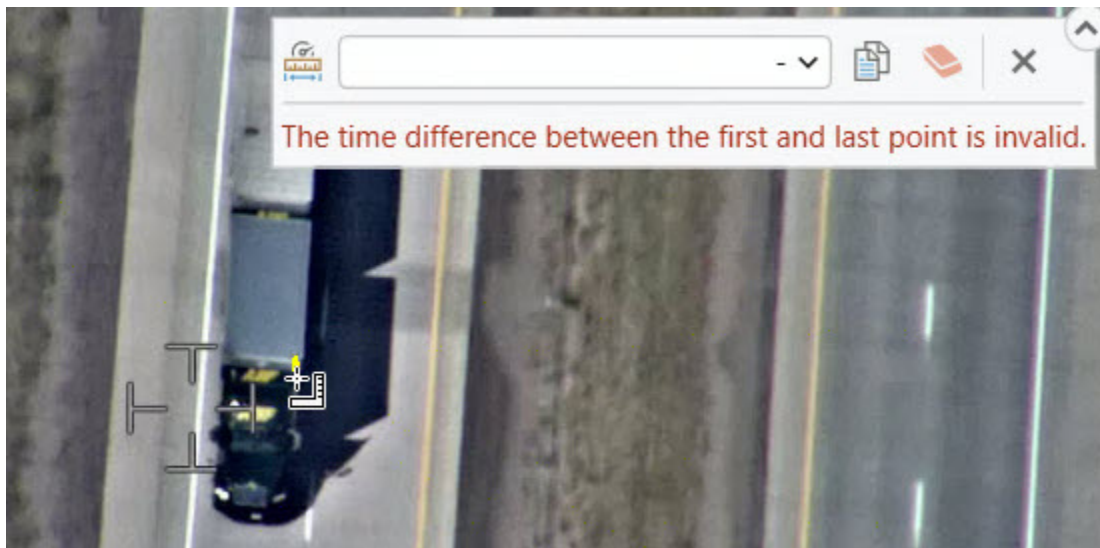
A window opens in the upper right of the video player. You can use the tools in the window to specify the measurement units, copy your results, and clear your results. You will set the measurement units to miles so that the speed of the vehicle is measured in miles per hour.

- b Click the down arrow and select Miles, as shown in the following graphic.



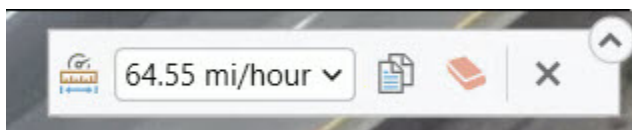
The field will remain blank until you start measuring the speed of the truck.

- c Click the bottom-right corner of the first trailer, as shown in the following graphic.



- d Click the Play button .

- e After the video plays for about 8 seconds, double-click the same location on the truck to calculate the speed.



After you double-click to finish measuring the speed of the truck, the speed is automatically calculated in miles per hour. The truck is traveling at approximately 65 miles per hour.



If you would like to retry the steps for measuring the speed of the truck, click the Clear Results button  to remove the speed that you previously measured and start the video from the beginning.

Now that you have determined the location and approximate speed of the truck, you can determine when it will arrive in Wellington and, subsequently, the airfield.

Step 4: Measure travel distance

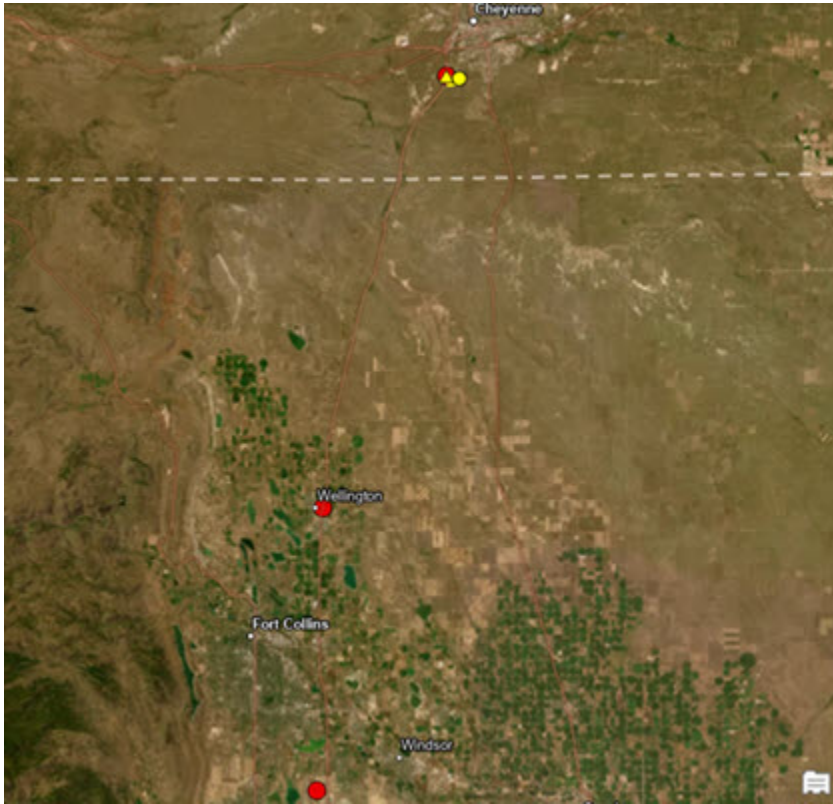
To give field agents extra time to get in position and ensure that they will not miss the passing truck, you will determine travel times based on the truck traveling at 70 mph.

- a In the Contents pane, turn on the FBI_locs layer.
- b On your own, create a feature in the FBI_locs feature layer that represents the last known location of the truck.

Hint: Activate the map view and, from the Edit tab, use the Create Features tool to place a point along I-25 where the truck is located on the map.

- c Save your edits.
- d Zoom to the FBI_locs feature layer.

- e Clear any selections that you may have active and close the Create Features pane.



- f From the Map tab, in the Inquiry group, click Measure to open the Measure tool, and then set it to measure in miles.
- g On your own, trace along the line representing Highway 25 to measure the distance that the truck has to travel to both Wellington, Colorado, and the Northern Colorado Regional Airport.



Remember that you are using a travel speed of 70 mph to give enough extra time for agents to get in place. Divide the total miles traveled by the speed of the vehicle to determine approximate drive time.

5. At what date and time will the truck arrive in Wellington?

Hint: Add estimated travel time to the timestamp at the last known location that you used to measure the travel distance.

6. At what date and time will the truck arrive at the Northern Colorado Regional Airport?

Hint: Add estimated travel time to the timestamp at the last known location that you used to measure the travel distance.



Your answers may be different depending on the distance measured between the locations.

You have identified the approximate times that the truck will arrive at both Wellington and the Northern Colorado Regional Airport. You can provide this information to the interdiction team.

 Save your project and exit ArcGIS Pro.

Geospatial video in 3D

Sensor dynamics and field of view can be visualized in ArcGIS Pro in both 2D maps and 3D scenes. In 2D, graphics displayed on the map correspond to the video footprint, the sensor look angle, and the sensor path and location. Though both options provide context to the video, whether it is a saved video clip or live feed, 3D scenes provide additional information valuable to mission planning and support.

- Visualizing flight path of platform
- Increased visualization of area surrounding the target
- More accurate representation of the sensor collection footprint

Lesson review

1. Motion imagery sensors provide a HUD that contains valuable information, such as the sensor location and location of what the sensor is pointed at.
 - a. True
 - b. False
2. Which organization is responsible for formulating, reviewing, and recommending standards for motion imagery, metadata, audio, and related systems?
 - a. MISB
 - b. NGS
 - c. MISP
 - d. NGA
3. ArcGIS Pro provides the capability to analyze and edit feature data in the video player.
 - a. True
 - b. False

Answers to lesson 8 questions

Exercise 8: Use geospatial video for intelligence analysis (page 8-6)

1. What is the nearest major city?

Cheyenne, Wyoming

2. What is the date and time shown on the motion imagery footage?

19SEP2012 at 14:51:02.245 UTC -6 (20:51:02.245Z)

3. In which direction is the truck traveling?

South

4. On which interstate is the truck traveling?

Interstate 25

5. At what date and time will the truck arrive in Wellington?

Approximately 19SEP2012 at 15:15 UTC -6 (21:15Z)

6. At what date and time will the truck arrive at the Northern Colorado Regional Airport?

Approximately 19SEP2012 at 15:30 UTC -6 (21:30Z)

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Data license agreement (continued)

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Data license agreement (continued)

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Appendix A

Data license agreement (continued)

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Appendix B

Acknowledgments

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[/mapCenter=-119.60863%2C35.99247%2C10.796&mode=analysis&mainScene=%7CSWI+Colorized](https://livingatlas.arcgis.com/sentinel1explorer/#mapCenter=-119.60863%2C35.99247%2C10.796&mode=analysis&mainScene=%7CSWI+Colorized)
- “Sentinel-1 Explorer - Vancouver, Canada.” European Space Agency (ESA) and European Commission. Scene ID
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Appendix B

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Appendix C

Answers to lesson review questions

Answers to lesson 1 review questions

1. Which type of imagery collection platform will collect imagery frequently over a small collection area?
a. UAV
2. Which raster type comes from the vendor and includes commonly used raster function templates?
c. Raster product

Answers to lesson 2 review questions

1. When measuring oblique imagery, you should take measurements from clearly defined and corresponding object-shadow points to ensure the accuracy of the measurements.
a. True
2. What are MCS and ICS, and what are they used for?
MCS stands for map coordinate system, and it is used to display vertical imagery. ICS stands for image coordinate system, and it is primarily used to display oblique imagery.
3. Which metadata field contains information related to which face of a building that you will see when analyzing oblique imagery?
c. Collection angle

Appendix C

Answers to lesson review questions (continued)

Answers to lesson 3 review questions

1. Why is it important to preprocess your images before performing a change detection?

It ensures that you measure and identify actual change. Preprocessing accounts for radiometric variance, especially for satellite imagery, which collects all reflected energy through the atmosphere. Because the atmosphere is in a state of constant flux, as well as the variations in collection angle, sun azimuth, and sun elevation, images collected on two different dates will have slightly different image return values—even for an unchanged feature. Correcting for environmental factors ensures that the observed spectral values are comparable with each other and baselined to a similar scale.

2. What differentiates visual change detection from change detection using a raster function?

Raster functions give you the ability to find potential change across a wide area. Visual change detection only highlights or shows differences that you can readily see. Additionally, raster functions allow you to measure the change and potentially quantify the amount of change in the battlespace.

Answers to lesson 4 review questions

1. How does object-based classification differ from pixel-based classification?

Object-based classification uses neighboring pixels during training. It evaluates how similar neighboring pixels to the pixel in question are. This process is known as segmentation. With pixel-based classification, each pixel is evaluated individually, often resulting in a "salt-and-pepper" effect from the classification process.

Appendix C

Answers to lesson review questions (continued)

2. Which image classification method requires user-defined training samples to recognize specific features?
c. Supervised

Answers to lesson 6 review questions

1. How does a training sample with mixed features (for example, two types of pavement) affect classification results?
There is a strong possibility of class/category confusion. This confusion might lead to the concrete/pavement being misclassified, but other features that may be spectrally similar may also be misclassified.
2. What differentiates an unsupervised pixel-based classification workflow from a supervised object-based workflow?
**At the "method" level, supervised classification requires user-defined training samples and some up-front knowledge of the AOI. The user "supervises" the amount and type of features to classify. Unsupervised classification relies on the software and statistics to evaluate the pixels in n-dimensional space (n = number of bands).
From a "type" level, object-based classification (coupled with strong training samples) gives the analyst a stronger possibility of high-accuracy results. The object-based classification type more closely represents how humans visually understand imagery. It groups pixels into the shapes of real-world features and can produce a cleaner result because you have less noise from individual pixels. Grouping pixels into segments creates additional spectral attributes (for example, mean or standard deviation) and spatial attributes (for example, compactness or rectangularity) that the classifiers can use.**

Appendix C

Answers to lesson review questions (continued)

Answers to lesson 7 review questions

1. Describe the difference between active and passive remote sensing.
With active remote sensing, a sensor transmits electromagnetic waves and measures the backscatter; with passive remote sensing, a sensor records reflected solar energy.
2. Which processing step is used to orthorectify a SAR image?
b. Geometric terrain correction

Answers to lesson 8 review questions

1. Motion imagery sensors provide a HUD that contains valuable information, such as the sensor location and location of what the sensor is pointed at.
a. True
2. Which organization is responsible for formulating, reviewing, and recommending standards for motion imagery, metadata, audio, and related systems?
a. MISB
3. ArcGIS Pro provides the capability to analyze and edit feature data in the video player.
a. True

Appendix D

Additional resources

Lesson 1	Resources
Imagery in ArcGIS Pro	• <i>ArcGIS Pro Help: Introduction to NITF data</i>

Lesson 3	Resources
Common raster functions used in the defense industry	• <i>ArcGIS Pro Help: List of raster functions</i>

Lesson 7	Resources
SAR processing	• <i>ArcGIS Pro Help: Sensor support for synthetic aperture radar sensors</i>

Lesson 8	Resources
Motion imagery in ArcGIS Pro	• <i>ArcGIS Pro Help: Introduction to geospatial video</i>
Geospatial video in ArcGIS Pro	• <i>ArcGIS Pro Help: Work with the geospatial video player</i>

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