

# RASTER ANALYSIS

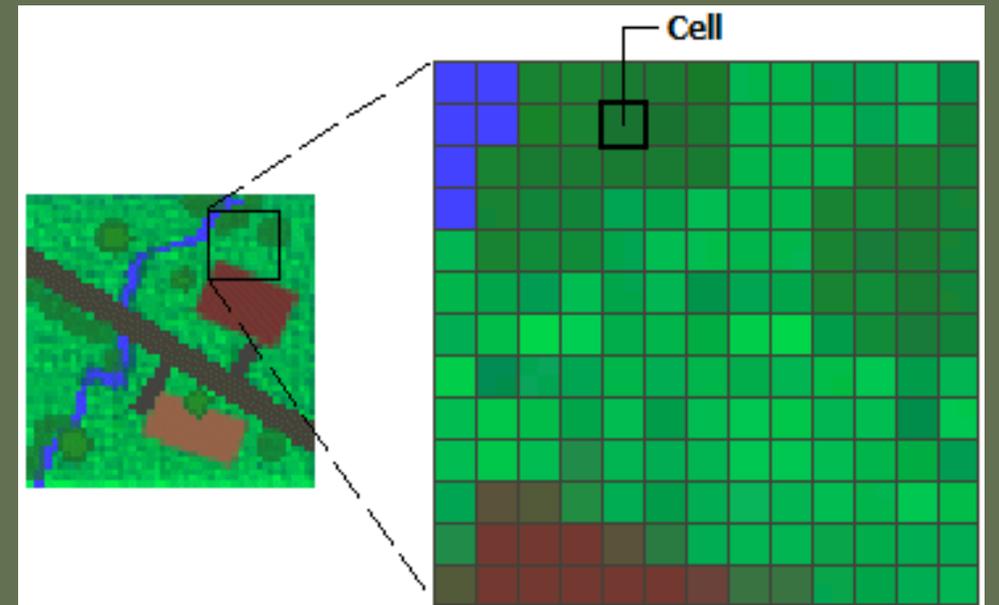
Sandeep Talasila, GISP



# BASICS

- Simple data structure
- Real-world phenomena
  - Thematic – land use, soils
  - Continuous data – imagery, temperature, precipitation, elevation
  - Pictures – scanned maps or drawings

<https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/introduction-to-raster-data.htm>



# CHARACTERISTICS OF RASTER

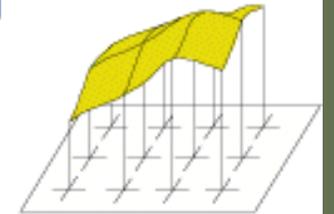
Each cell has a value representing the attributes such as

- Category – land use class: grassland, forest, urban,...
- Magnitude – percent rainfall
- Height – elevation
- Spectral value – light reflectance

## Value applies to the center point of the cell

For certain types of data, the cell value represents a measured value at the center point of the cell. An example is a raster of elevation

|          |          |          |          |
|----------|----------|----------|----------|
| +<br>315 | +<br>319 | +<br>321 | +<br>323 |
| +<br>317 | +<br>323 | +<br>328 | +<br>326 |
| +<br>313 | +<br>318 | +<br>325 | +<br>323 |



## Value applies to the whole area of the cell

For most data, the cell value represents a sampling of a phenomenon, and the value is presumed to represent the whole cell square.

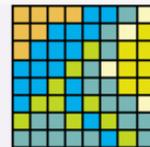
|    |    |    |    |
|----|----|----|----|
| 50 | 45 | 40 | 35 |
| 35 | 40 | 35 | 25 |
| 20 | 25 | 30 | 20 |



# DATA TYPES AND CELL VALUES

The data stored in a raster can be categorized as one of these types.

## Nominal data



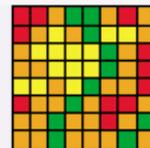
- Orange: Fir
- Blue: Juniper
- Yellow: Aspen
- Light blue: Piñon
- White: Cottonwood
- Light yellow: Walnut

Nominal data values are categorized and have names. The data value is an arbitrary type code. Examples are soil types and land use.

|    |    |    |    |    |    |
|----|----|----|----|----|----|
| 21 | 17 | 17 | 18 | 22 | 18 |
| 18 | 16 | 17 | 19 | 24 | 19 |
| 21 | 19 | 19 | 19 | 22 | 22 |
| 26 | 23 | 21 | 20 | 18 | 21 |
| 24 | 23 | 18 | 16 | 20 | 19 |
| 18 | 14 | 16 | 17 | 19 | 20 |

Nominal and ordinal data represent discrete categories. They are best represented with integer cell values.

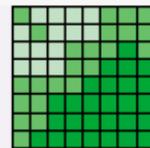
## Ordinal data



- Green: very good
- Yellow: good
- Orange: moderate
- Red: poor

Ordinal data values are categorized, have names, and the value is in a numerical rank. Examples are land suitability classifications and soil drainage rank.

## Interval data



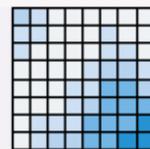
- Lightest green: 700–709
- Light green: 710–719
- Medium green: 720–729
- Dark green: 730–739
- Very dark green: 740–749
- Darkest green: 750–759

Interval data values are numerically ordered and the interval difference is meaningful. Examples are voltage potential and difference in concentration.

|      |      |      |      |
|------|------|------|------|
| 21.1 | 17.3 | 17.2 | 18.1 |
| 18.5 | 16.2 | 17.3 | 19.1 |
| 21.0 | 19.1 | 19.4 | 19.2 |
| 26.3 | 23.1 | 21.6 | 20.5 |

Interval and ratio data present continuous phenomena and are usually measured with real cell values.

## Ratio data



- Lightest blue: 0.0–10.0
- Light blue: 10.1–20.0
- Medium blue: 20.1–30.0
- Dark blue: 30.1–40.0
- Darkest blue: 40.1–50.0

Ratio data values measure a continuous phenomenon with a natural zero point. Examples are rainfall and population.

# RASTER – ADVANTAGES AND LIMITATIONS

## Advantages

- A simple data structure
- Format used in advanced spatial and statistical analysis
- Uniformly stores points, lines, and polygons
- Performs fast overlays with complex datasets

## Limitations

- Spatial inaccuracies due to cell dimensions
- Raster datasets can be very large. Resolution increases as the size of the pixel decreases
- Loss of geometric precision

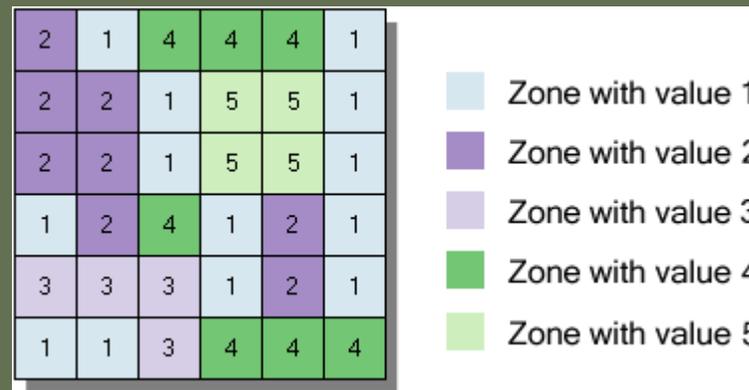
# ZONES AND REGIONS

## Zones

- Groups of cells with the same value that are contiguous or noncontiguous.

## Regions

- Each group of contiguous cells that have the same value is considered a region.



# SINGLE BAND RASTERS

Cell values in single-band rasters can be drawn in these three basic ways.

**Monochrome image**

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 | 0 |

|   |   |
|---|---|
| 0 | 1 |
|---|---|

In a monochrome image, each cell has a value of 0 or 1. They are often used for scanning maps with simple linework, such as parcel maps.

**Grayscale image**

|     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|
| 68  | 124 | 0   | 170 | 86  | 0   |
| 234 | 187 | 68  | 251 | 10  | 236 |
| 76  | 124 | 218 | 132 | 201 | 66  |
| 124 | 16  | 118 | 183 | 32  | 255 |
| 126 | 191 | 198 | 251 | 141 | 56  |
| 41  | 255 | 243 | 162 | 212 | 152 |

|   |     |
|---|-----|
| 0 | 255 |
|---|-----|

In a grayscale image, each cell has a value from 0 to 255. They are often used for black-and-white aerial photographs.

**Display colormap image**

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 5 | 3 | 2 | 2 | 4 |
| 5 | 2 | 4 | 2 | 5 | 1 |
| 5 | 5 | 5 | 5 | 3 | 3 |
| 2 | 1 | 2 | 4 | 1 | 3 |
| 4 | 4 | 4 | 1 | 1 | 3 |
| 2 | 4 | 2 | 1 | 3 | 3 |

|   |
|---|
| 1 |
| 2 |
| 3 |
| 4 |
| 5 |



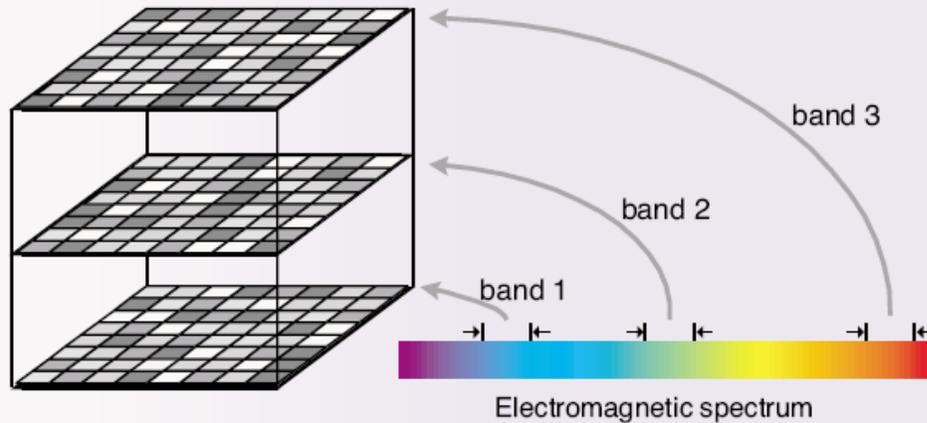
**Colormap**

|   | red | green | blue |
|---|-----|-------|------|
| 1 | 255 | 255   | 0    |
| 2 | 64  | 0     | 128  |
| 3 | 255 | 32    | 32   |
| 4 | 128 | 255   | 128  |
| 5 | 0   | 0     | 255  |

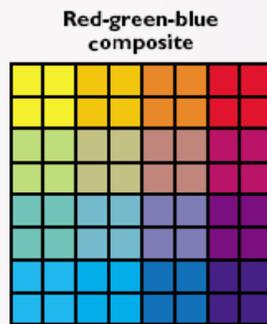
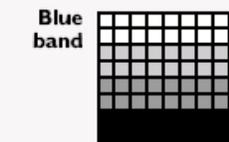
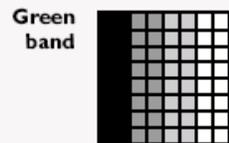
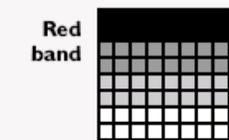
One way to represent colors on an image is with a colormap. A set of values is arbitrarily coded to match a defined set of red-green-blue values.

# MULTIBAND RASTERS

Raster datasets have one or many bands. In multiband rasters, a band represents a segment of the electromagnetic spectrum that has been collected by a sensor.



Bands often represent a portion of the electromagnetic spectrum, including ranges not visible to the eye—the infrared or ultraviolet sections of the spectrum.

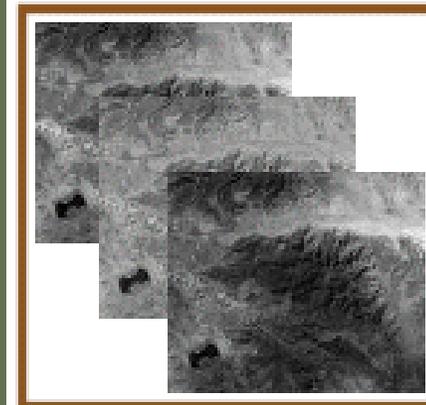


Attribute values range from 0 to 255 in each band



Multiband rasters are often displayed as red-green-blue composites. This band configuration is common because these bands can be directly displayed on computer displays, which employ a red-green-blue color rendition model.

Multiband raster dataset

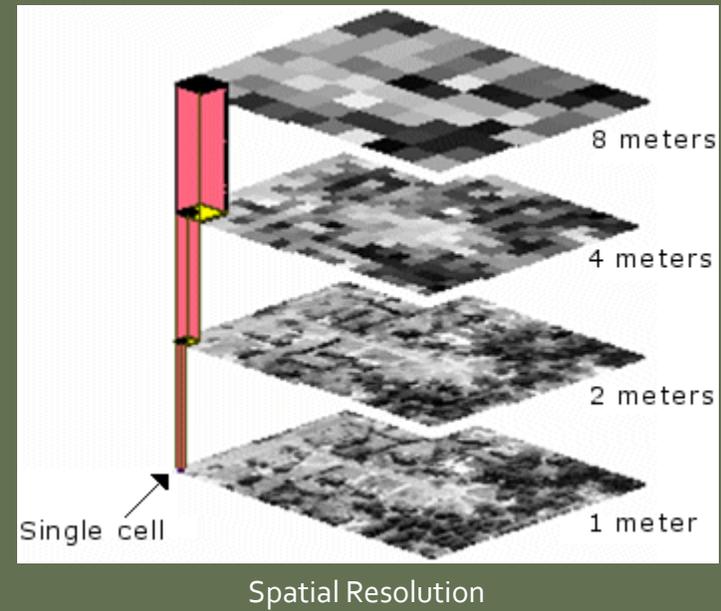


RGB composite

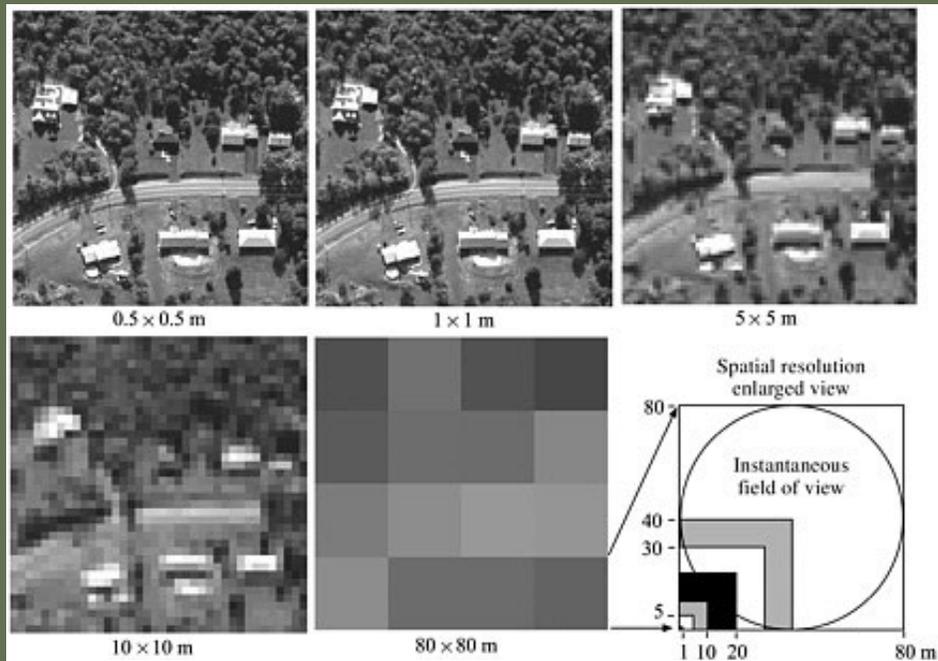


# RESOLUTION

- Spatial
- Spectral
- Temporal
- Radiometric

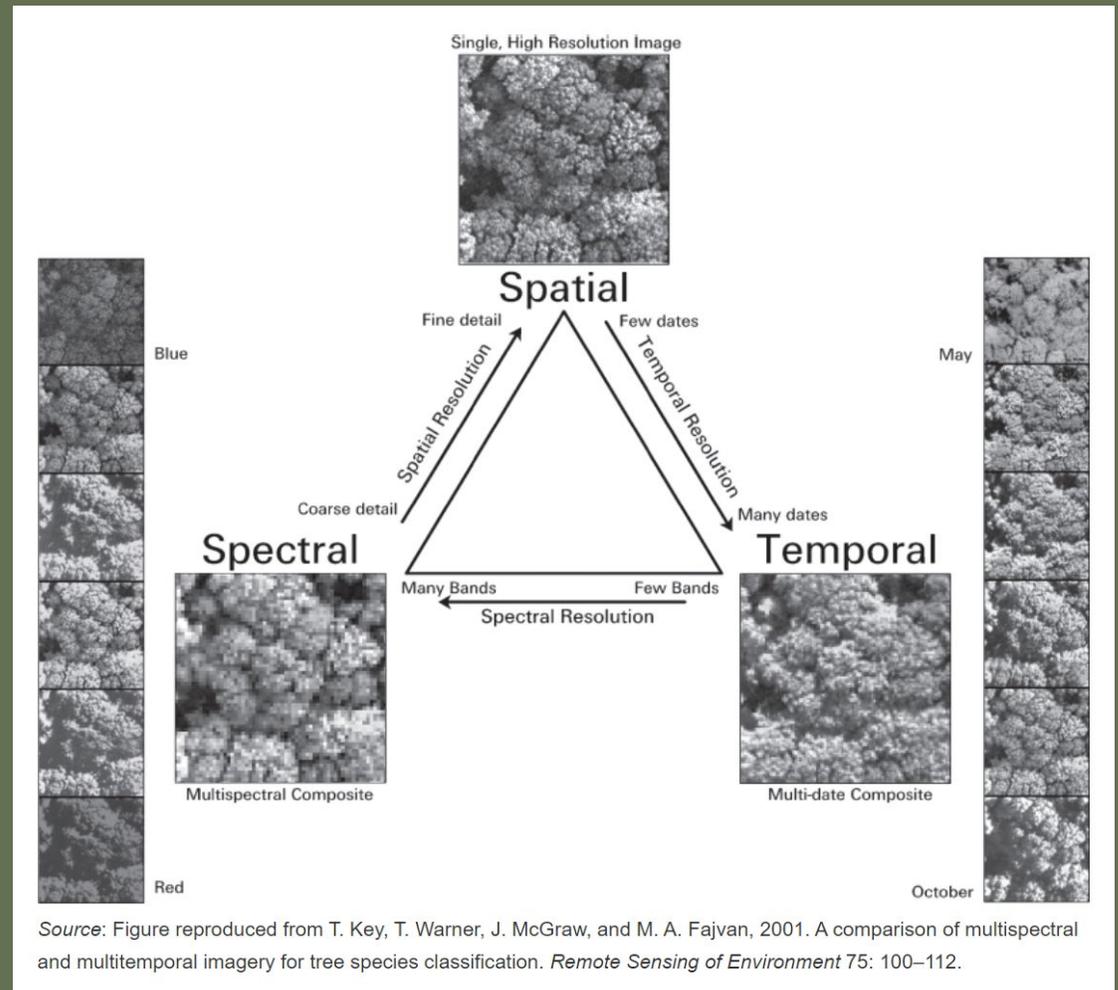


# RESOLUTION



[www.nap.edu](http://www.nap.edu)

The SAGE Handbook of Remote Sensing  
[methods.sagepub.com](http://methods.sagepub.com)



Source: Figure reproduced from T. Key, T. Warner, J. McGraw, and M. A. Fajvan, 2001. A comparison of multispectral and multitemporal imagery for tree species classification. *Remote Sensing of Environment* 75: 100–112.

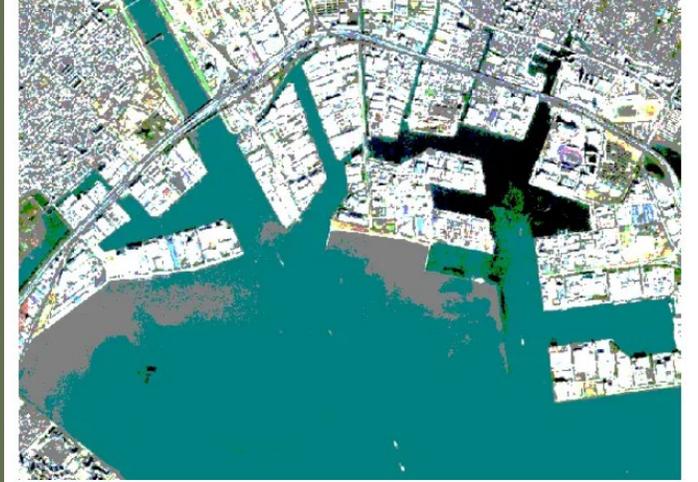
# RADIOMETRIC RESOLUTION



Radiometric Resolution 8-Bit | Sentinel 2 – Tokyo Coast



Radiometric Resolution 4-Bit | Sentinel 2 – Tokyo Coast



Radiometric Resolution 2-Bit | Sentinel 2 – Tokyo Coast

# RASTER INFORMATION

- Format – type used to store the raster.
- Columns and Rows – number of rows and columns.
- Number of bands – number of spatially coincident layers in the raster.
- Cell Size (X, Y) – size of each pixel.
- Data type/Pixel type – type of values stored in the raster, such as signed integer, unsigned integer, or floating point.
- Data depth/Pixel or bit depth – determines the possible range of values stored in each band.
- Statistics – include the minimum value in the raster, maximum value, mean of all values, and standard deviation.
- Extents – left, right, top, and bottom coordinates of the raster dataset.
- Projection – raster's coordinate system.
- Size of the raster – the number of rows and columns or the uncompressed size.

# RASTER INFORMATION

The image shows two overlapping windows of the 'Raster Dataset Properties' dialog box for the file 'm\_3110406\_ne\_13\_060\_20200926.tif'. The foreground window is focused on the 'Raster Information' tab, which displays a table of properties. The background window shows the 'General' tab with a tree view of the dialog's sections.

**Raster Dataset Properties : m\_3110406\_ne\_13\_060\_20200926.tif**

Find data source properties

General

- > Data Source
- > Raster Information
- > Band Metadata
- > Extent
- > Spatial Reference

OK

**Raster Dataset Properties : m\_3110406\_ne\_13\_060\_20200926.tif**

Find data source properties

General

▼ Raster Information

| Property                 | Value                                   |
|--------------------------|---|
| Columns                  | 10590                                   |
| Rows                     | 12280                                   |
| Number of Bands          | 4                                       |
| Cell Size X              | 0.600000                                |
| Cell Size Y              | 0.600000                                |
| Uncompressed Size        | 496.08 MB                               |
| Format                   | TIFF                                    |
| Source Type              | Generic                                 |
| Pixel Type               | unsigned char                           |
| Pixel Depth              | 8 Bit                                   |
| NoData Value             |   |
| Colormap                 | absent                                  |
| Pyramids                 | levels: 6, resampling: Nearest Neighbor |
| Compression              | None                                    |
| Mensuration Capabilities | Basic                                   |
| Geodata Transform        | Defined                                 |

OK Cancel

# DISPLAY

- Classified using the Symbology properties
- Cells are given a solid color based on cell values
- Symbology of Imagery:
  - Stretch
  - RGB Composite
  - Classify
  - Colormap
  - Discrete Color
  - Unique values
  - Shaded Relief
  - Vector Field

# STRETCH

The image shows a screenshot of the ArcGIS interface. On the left, the 'Contents' pane shows a map layer named 'm\_3110406\_ne\_13\_060\_20200926.tif' with a value range from 16 to 219. The main map area displays a grayscale satellite image of a landscape with a road and buildings. On the right, the 'Symbology' pane is open for the selected layer. It shows the following settings:

- Primary symbology: Stretch
- Band: Band\_1
- Color scheme: A grayscale gradient bar
- Invert
- Value: 16 (Min) to 219 (Max)
- Label: 16 (Min) to 219 (Max)
- Stretch type: Percent Clip
- Min: 0.500, Max: 0.500
- Gamma: 1.0

At the bottom of the Symbology pane, there are tabs for 'Statistics', 'Mask', and 'Advanced Labeling'. The 'Statistics' tab is active, showing 'Dataset' as the selected option.

# RGB COMPOSITE

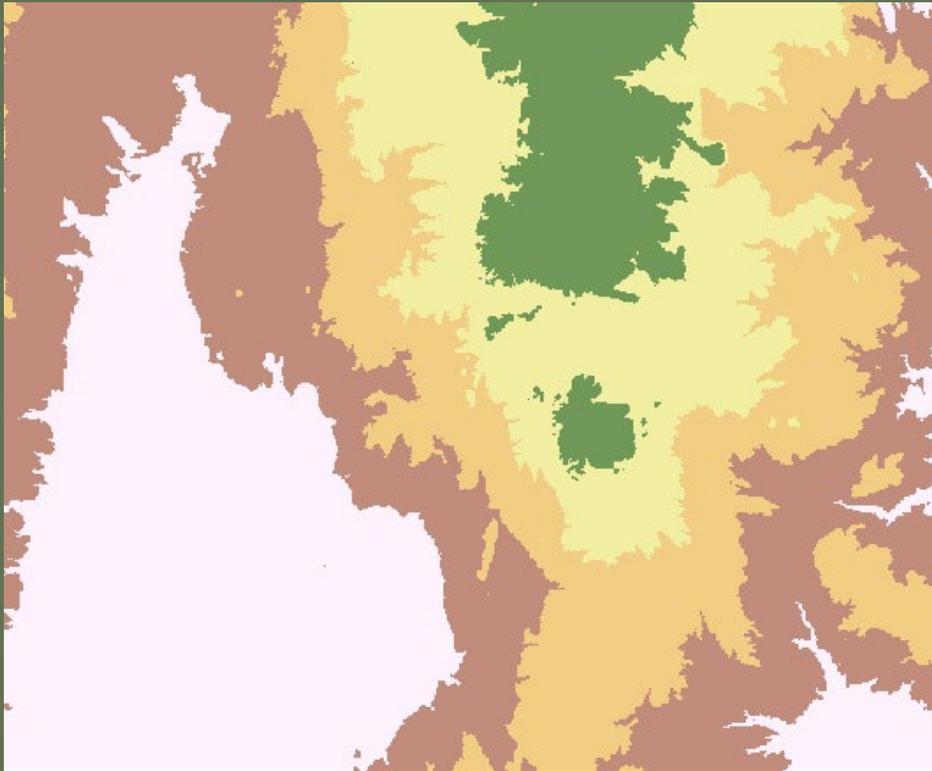
The image displays a GIS interface with a map window showing a satellite image overlaid on a topographic map. The Contents pane on the left shows the following layers in drawing order:

- Map
- m\_3110406\_ne\_13\_060\_20200926.tif (RGB)
  - Red: Band\_1
  - Green: Band\_2
  - Blue: Band\_3
- World Topographic Map
- World Hillshade

The Symbology pane for the RGB composite shows the following settings:

- Primary symbology: RGB
- Red: Band\_1
- Green: Band\_2
- Blue: Band\_3
- Alpha: None
- Invert
- Stretch type: Percent Clip
- Min: 0.500
- Max: 0.500
- Gamma: 1.0
- Statistics: Mask
- Statistics: Dataset

# CLASSIFIED



**Primary symbology**

Classify

Field *No fields*

Normalization *No fields*

Method Natural Breaks (Jenks)

Classes 5

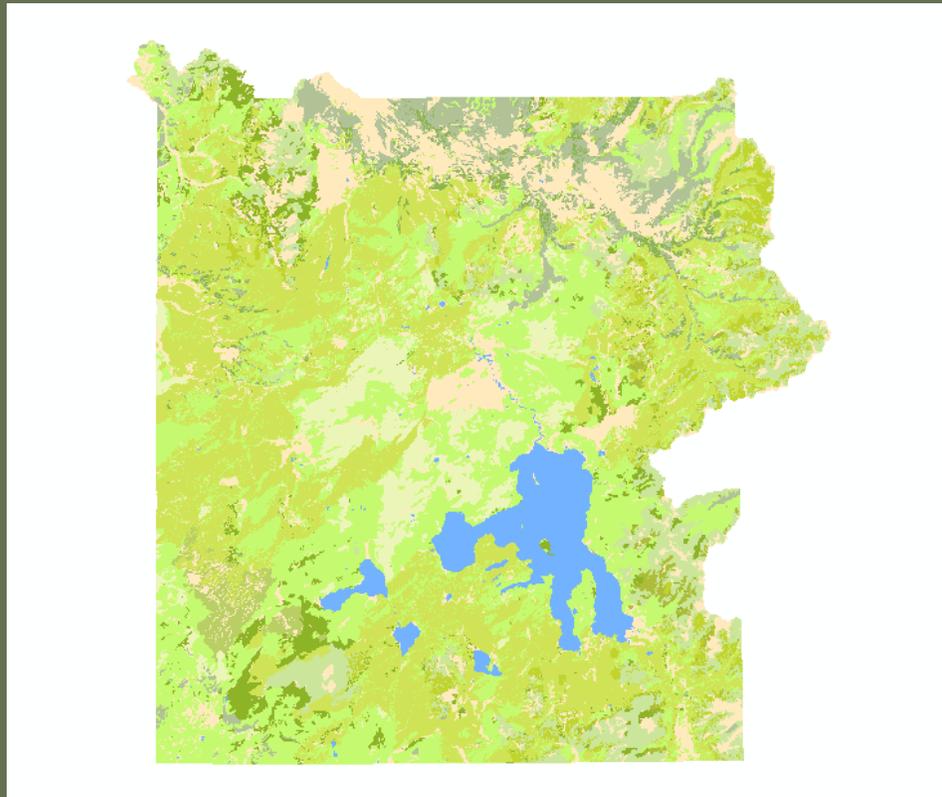
Color scheme

Classes Mask Histogram

More + 0.0 - 0.0

| Color | Upper value | Label         |
|-------|-------------|---------------|
|       | ≤ 36.0      | 0.001 - 36    |
|       | ≤ 87.0      | 36.001 - 87   |
|       | ≤ 116.0     | 87.001 - 116  |
|       | ≤ 139.0     | 116.001 - 139 |
|       | ≤ 254.0     | 139.001 - 254 |

# UNIQUE VALUES



Layer Properties

General Source Extent Display Symbology Fields Joins & Relates

Show:  
Unique Values  
Classified  
Stretched  
Colormap  
Discrete Color

Draw raster assigning a color to each value Import...

Value Field: CLASS\_NAMES

Color Scheme:

| Symbol                 | <VALUE>                          | Label                            | Count    |
|------------------------|----------------------------------|----------------------------------|----------|
|                        | <all other values>               | <all other values>               |          |
| <b>&lt;Heading&gt;</b> |                                  |                                  |          |
| <b>Class_Names</b>     |                                  |                                  |          |
|                        | cool aspect scarps, cliffs, cany | cool aspect scarps, cliffs, cany | 8696407  |
|                        | gently sloping ridges and hills  | gently sloping ridges and hills  | 41668537 |
|                        | hot aspect scarps, cliffs, canyo | hot aspect scarps, cliffs, canyo | 10476067 |
|                        | moderately dry slopes            | moderately dry slopes            | 15765298 |
|                        | moderately moist steep slopes    | moderately moist steep slopes    | 14869782 |
|                        | nearly level plateaus or terrace | nearly level plateaus or terrace | 52497511 |
|                        | null                             | null                             | 89002863 |

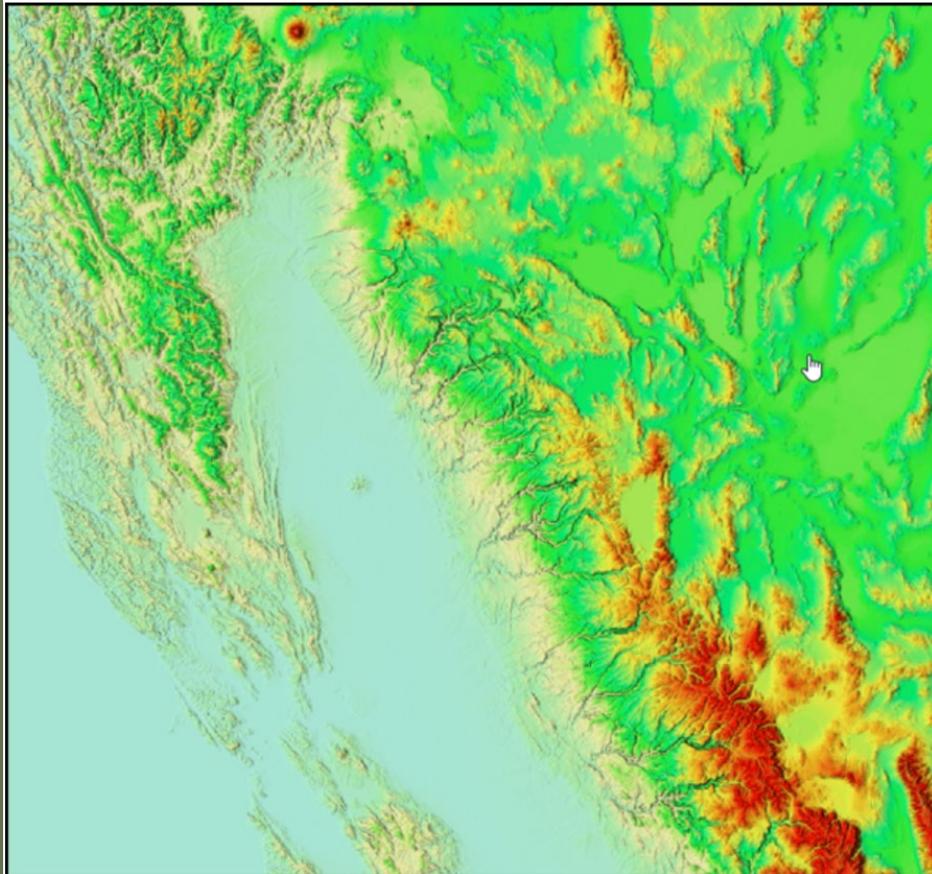
Add All Values Add Values... Remove

Default Colors

Colormap Display NoData as

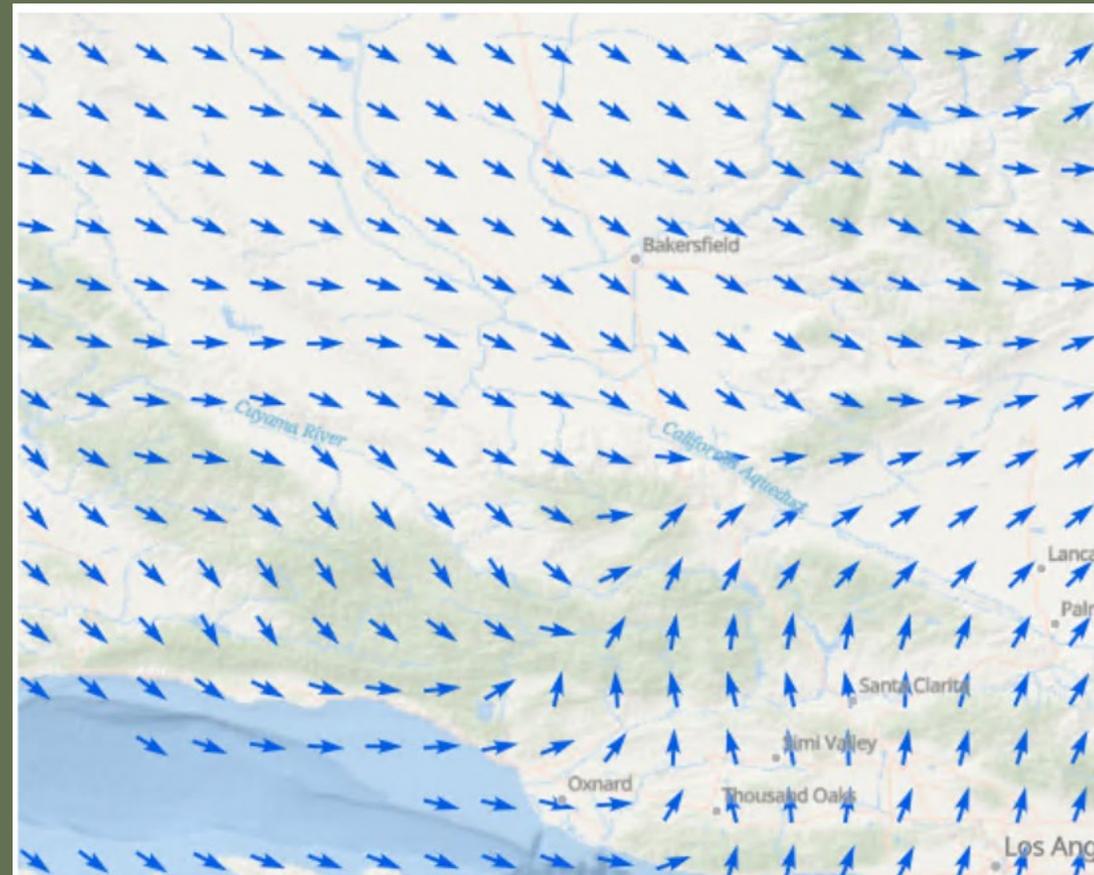
OK Cancel Apply

# SHADED RELIEF



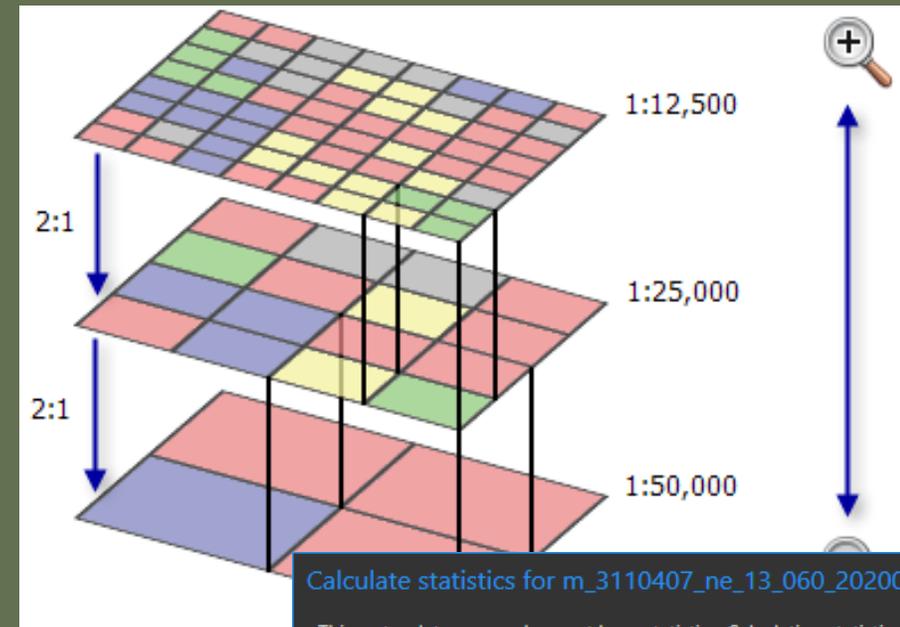
- Can choose color scheme and illumination source for hill shade

# VECTOR FIELD



# PYRAMIDS

- Downsampled version of the original raster
- Used to improve performance
- Each successive layer of the pyramid is downsampled at a scale of 2:1
- Create once and use many times
- \*.ovr or \*.rrd files
- Sampling
  - Nearest neighbor
  - Bilinear convolution
  - Cubic convolution



Calculate statistics for m\_3110407\_ne\_13\_060\_20200926.tif

This raster data source does not have statistics. Calculating statistics may take some time, but it will only need to be performed once for this dataset.

Statistics allow for a better display of your data, allowing contrast adjustments and display enhancements. Would you like to calculate statistics?

> Options

Always use this choice

[Learn more about statistics](#)

Yes No Cancel

# COMPRESSION

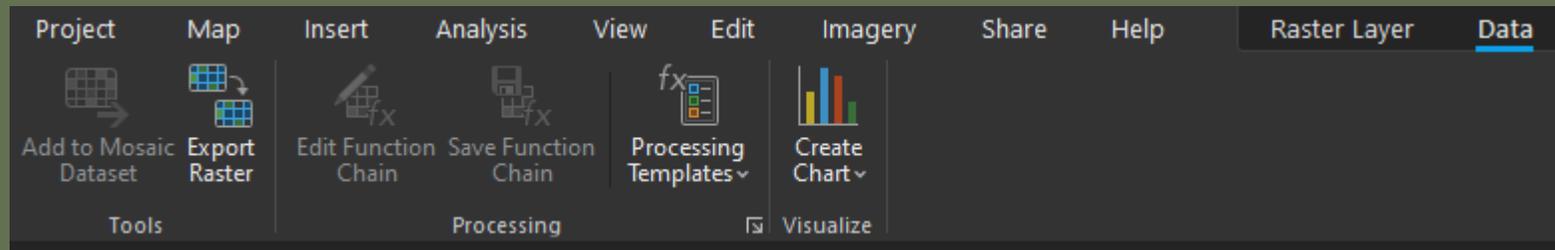
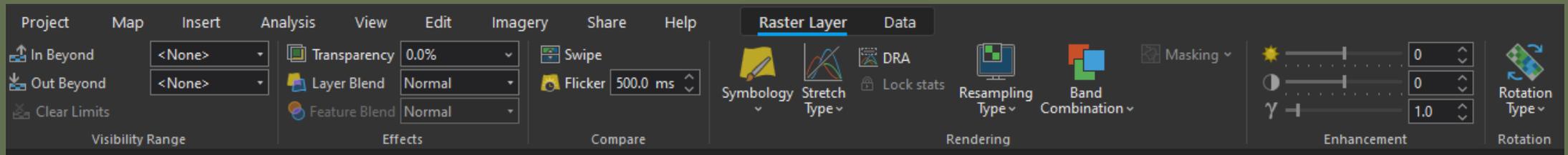
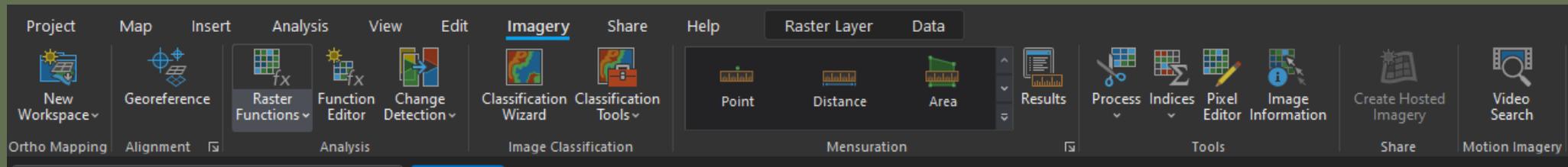
- Reduces file size
- Requires better CPU capabilities to decompress
- Possibly low resolution output
- Techniques: Transmission, Storage
- Types:
  - Lossy – JPEG, JPEG 2000
  - Lossless – LZW, LZ77, PackBits

# PROJECTION

- Defining spatial reference system for a raster dataset will have an effect on the cells, as they are permanently resampled to fit this projection.
- Defining spatial reference system for a mosaic dataset does not effect cells but the projection is used to create the footprints, boundaries, or other features.
- Each time a raster dataset is transformed, cells are resampled effecting image and data quality.

# ANALYSIS & PROCESSING

# IMAGE ANALYSIS TOOLS



# RASTER FUNCTIONS

Share Help Raster Layer Data

Classification Tools Deep Learning Tools

Point Distance

**Segmentation**  
Group neighboring pixels together based on their similarity, to create objects that are then used in image classification.

**Training Samples Manager**  
Create and manage training samples for supervised classification.

**Classify**  
Categorize pixels into classes.

Deep Learning Tools

Point Distance Area

**Label Objects for Deep Learning**  
Create and manage labeled objects for deep learning.

**Train Deep Learning Model**  
Train deep learning model using an assisted workflow.

**Review Deep Learning Models**  
Review deep learning model metrics.

Raster Functions

Find Raster Functions

Project System Custom

Analysis

- Binary Thresholding
- CCDC Analysis
- Compute Change
- Detect Change Usi...
- Generate Trend
- Gradient
- Heat Index
- Kernel Density
- LandTrend Analysis
- NDVI
- NDVI Colorized
- Predict Using Trend
- Process Raster Colle...
- Tasseled Cap (Kauth-Tho...
- Weighted Overlay
- Weighted Sum
- Wind Chill

Appearance

Classification

Conversion

Correction

Data Management

Distance

Distance (Legacy)

Hydrology

Math

- Math: Conditional
- Math: Logical
- Math: Trigonometric

Reclass

SAR

Statistical

Surface

- Aspect
- Aspect-Slope
- Contour
- Curvature
- Elevation Void Fill
- Hillshade
- Shaded Relief
- Slope
- Surface Parameters
- Viewshed

# RASTER FUNCTIONS VS GEOPROCESSING TOOLS

## Geoprocessing Tools

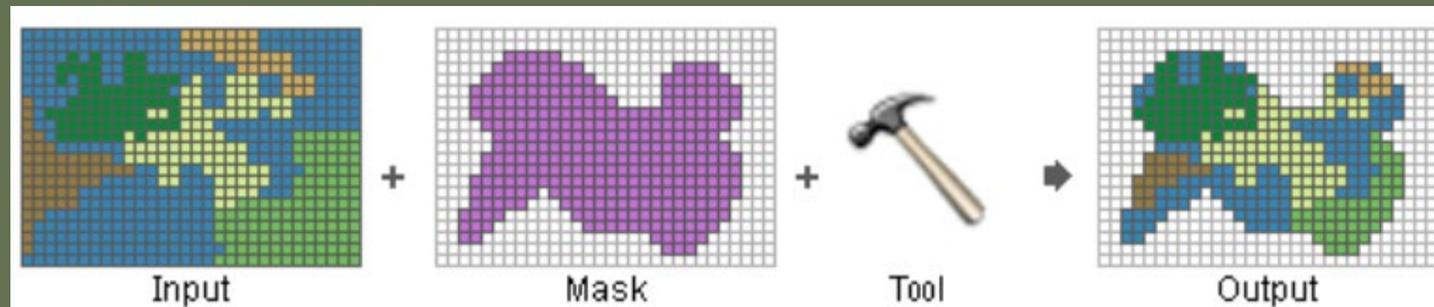
- Creates new data on disk
- Can view and edit geoprocessing history
- Can batch process
- Can combine processes for complex modeling
- ...

## Raster Functions

- No new dataset created
- Can view and edit raster function history
- On the fly processing and fast
- Create and use custom raster functions
- Generate processing templates for image services
- Can combine processes for complex modeling
- ...

# ANALYSIS MASK

- The mask identifies those cells within the analysis extent that will not be considered when performing an operation or a function.
- All identified cells will be "out" and assigned to the nodata value on all subsequent output raster datasets.



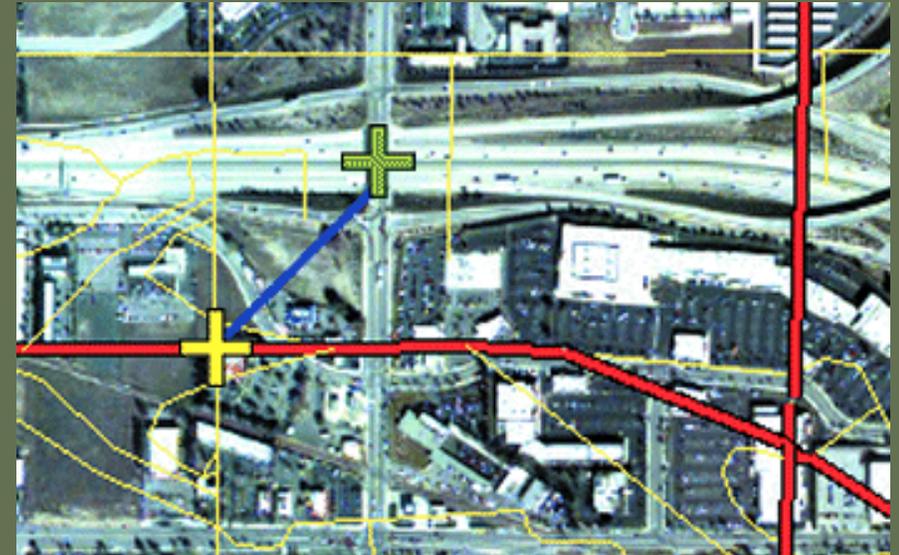
# GEOREFERENCING

# WHAT IS GEOREFERENCING?

- Georeferencing is the process of assigning real-world coordinates to each pixel of the raster.
- To align a raster image to a map coordinate system.
- Allows to view, query, and analyze the raster image with other geographic data.
- A georeferenced image will have coordinate system and projection of reference data.

# CONTROL POINTS

- Locations that can be accurately identified on the raster dataset and in real-world coordinates.
- Examples: Road or stream intersections, the mouth of a stream, rock outcrops, the end of a jetty of land, etc.
- The connection between one control point on the raster dataset and the corresponding control point on the aligned target data is called a link.

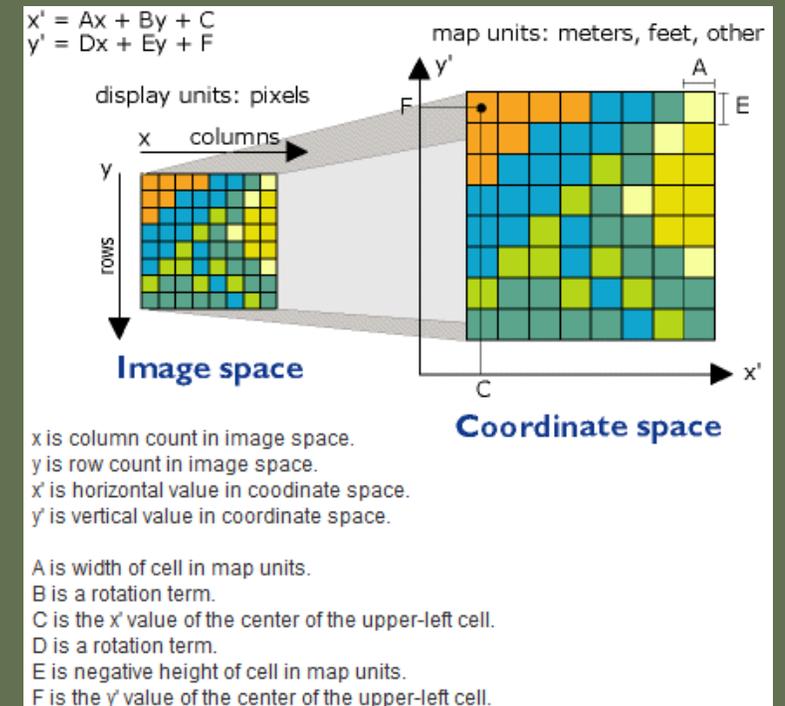


# HOW MANY CONTROL POINTS?

- Spread control points around image, try not to concentrate them in one area
- Typically, having at least one link near each corner of the raster dataset and a few throughout the interior produces the best results.
- The greater the overlap between the raster dataset and target data, the better the alignment results.
- Georeferenced data is only as accurate as the data to which it is aligned. To minimize errors, you should georeference to data that is at the highest resolution and largest scale for your needs.

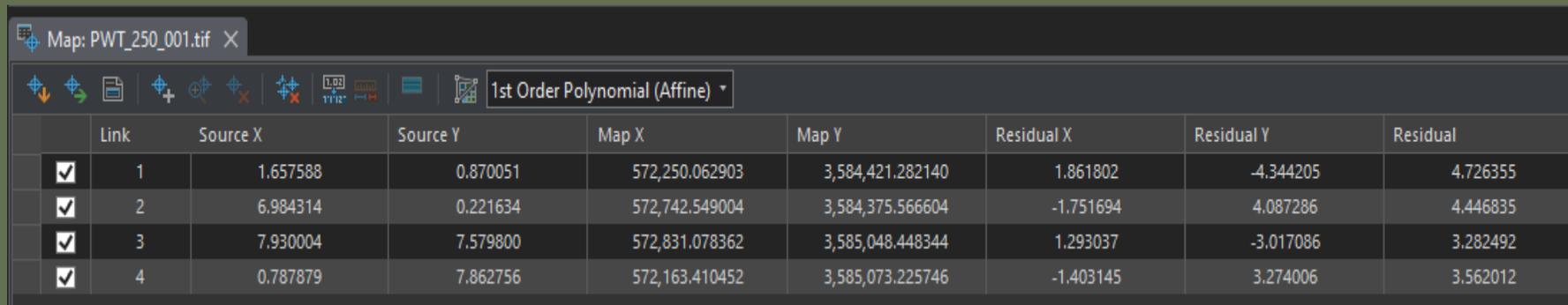
# TRANSFORMATION

- When you've created enough links, you can transform—or warp—the raster dataset to permanently match the map coordinates of the target data.
- Methods
  - Polynomial (Similarity, 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> or Zero order)
  - Spline
  - Adjust
  - Projective Transformation



# ROOT MEAN SQUARE ERROR (RMSE)

- Distance measuring concept to compare expected with measured data.
- The error is the difference between where the from point ended up as opposed to the actual location that was specified.
- The total error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS error.
- When the error is particularly large, you can remove and add control points to adjust the error.
- All residuals closer to zero are considered more accurate.



Map: PWT\_250\_001.tif

1st Order Polynomial (Affine)

|                                     | Link | Source X | Source Y | Map X          | Map Y            | Residual X | Residual Y | Residual |
|-------------------------------------|------|----------|----------|----------------|------------------|------------|------------|----------|
| <input checked="" type="checkbox"/> | 1    | 1.657588 | 0.870051 | 572,250.062903 | 3,584,421.282140 | 1.861802   | -4.344205  | 4.726355 |
| <input checked="" type="checkbox"/> | 2    | 6.984314 | 0.221634 | 572,742.549004 | 3,584,375.566604 | -1.751694  | 4.087286   | 4.446835 |
| <input checked="" type="checkbox"/> | 3    | 7.930004 | 7.579800 | 572,831.078362 | 3,585,048.448344 | 1.293037   | -3.017086  | 3.282492 |
| <input checked="" type="checkbox"/> | 4    | 0.787879 | 7.862756 | 572,163.410452 | 3,585,073.225746 | -1.403145  | 3.274006   | 3.562012 |

Georeferencing: PWT\_250\_001.tif

Transformation: 1st Order Polynomial (Affine)

Controls Points: 4 / 4

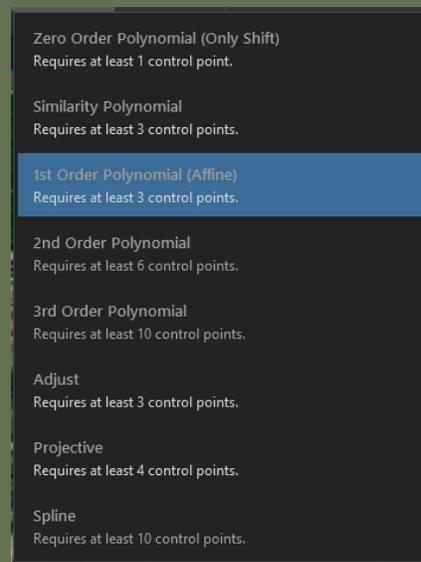
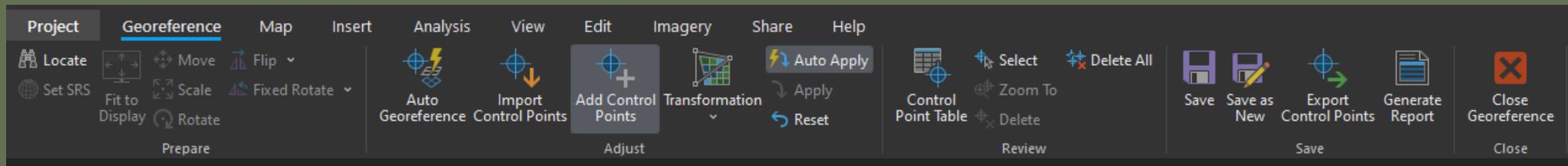
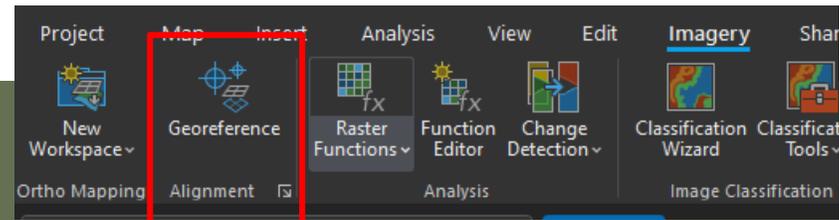
Total RMS Errors

Forward: 4.048934

Inverse: 0.043942

Forward-Inverse: 0.000000

# TOOLS



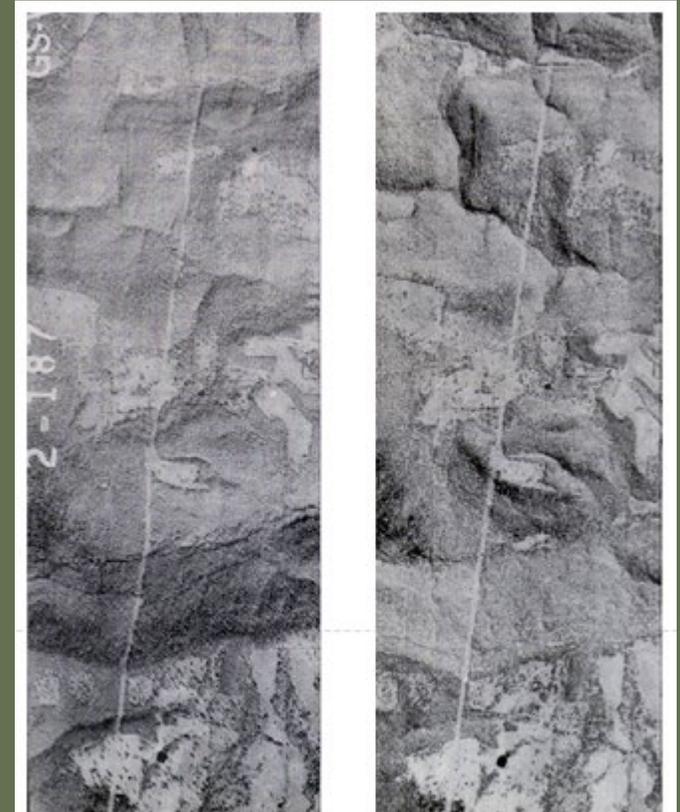
# SAVING GEOREFERENCED RASTER

- Save as New – permanently transforms your raster dataset (creates new dataset)
- Save – stores transformation information in auxiliary files
  
- More information <http://desktop.arcgis.com/en/arcmap/latest/manage-data/raster-and-images/fundamentals-for-georeferencing-a-raster-dataset.htm>
- Video <https://www.youtube.com/watch?v=PHtxbpboDro>

ORTHO RECTIFYING

# ORTHORECTIFICATION

- The process of stretching the image to correct geometric distortion and match the spatial accuracy of a map by considering location, elevation, and sensor information.
- Distortions in the images due to distortions from the sensor and the earth's terrain.
- Ortho Mapping involves edgematching, cutline generation, and color balancing for multiple images to produce an orthomosaic dataset.



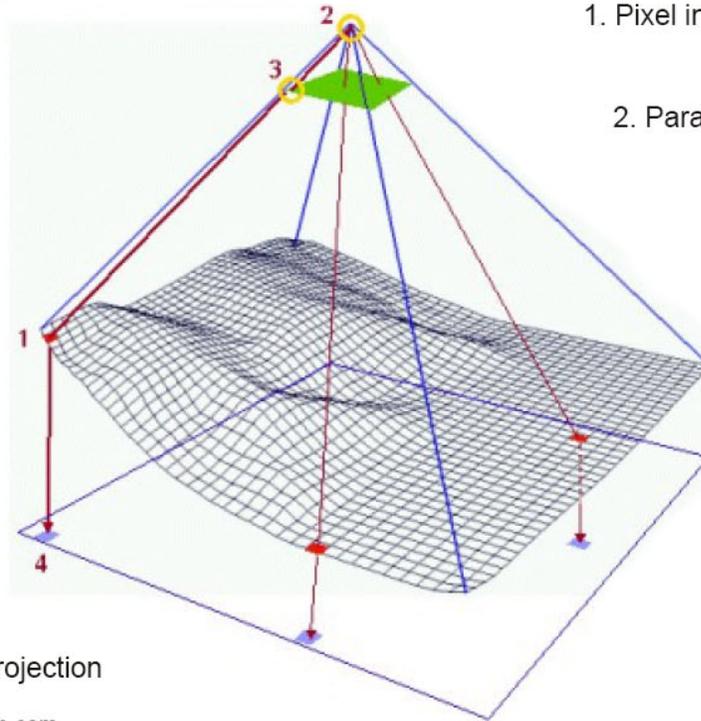
Above are 2 images of the same geographic area. Note the road that passes through the mountains. In the left "raw" or unrectified image, the road appears to be crooked when in fact it is not. The image on the right has been rectified image and the road appears planimetrically correct.

# PROCESS

- Requirements:
  - An accurate description of the sensor, typically called the sensor model
  - Detailed information about the sensor location and orientation for every image
  - An accurate terrain model
- An accurate orthorectified raster dataset can be produced using the rational polynomial coefficients (RPCs), if they are provided by the vendor, and an accurate digital elevation model (DEM).
- Spatial location in the image of a pixel can be improved by applying the information within the associated RPC file, that is, the coefficient to the latitude, longitude, and height value of the pixel.

# ORTHORECTIFICATION

Orthorectification process of remote sensed Image data



1. Pixel in the DEM (Height)

2. Parameters in the Exterior Orientation

3. In the image, a Brightness Value is determined based on the resampling of surrounding pixels

4. Height, Exterior Orientation information and Brightness Value used to calculate equivalent location in the orthoimage

Orthographic Projection

[www.satimagingcorp.com](http://www.satimagingcorp.com)

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