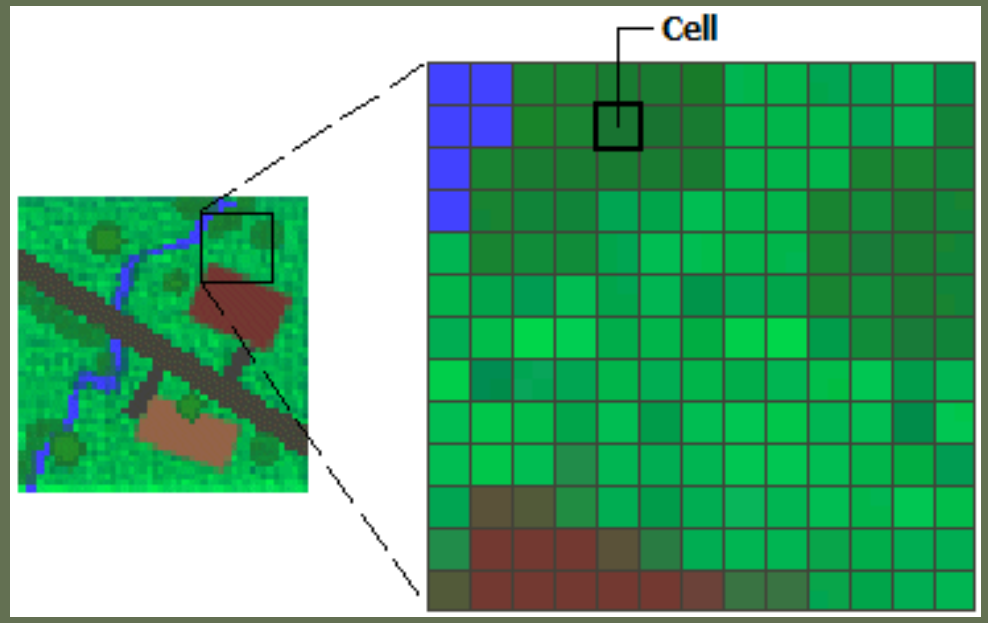
RASTER ANALYSIS

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

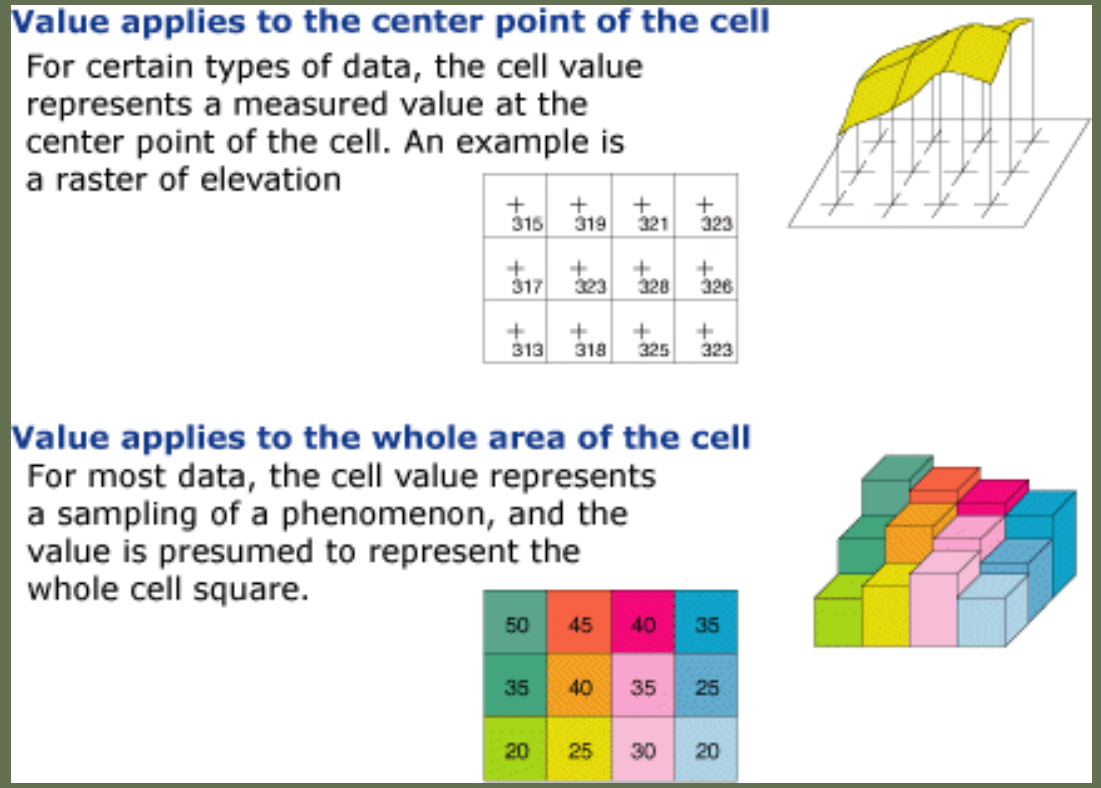


https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/introduction-to-raster-data.htm

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



DATA TYPES AND CELL VALUES

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

Nominal data

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

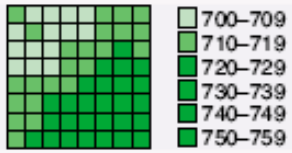
Ordinal data

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

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

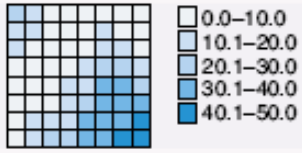
Nominal and ordinal data represent discrete categories. They are best represented with integer cell values.

Interval data



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

Ratio data



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

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.

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

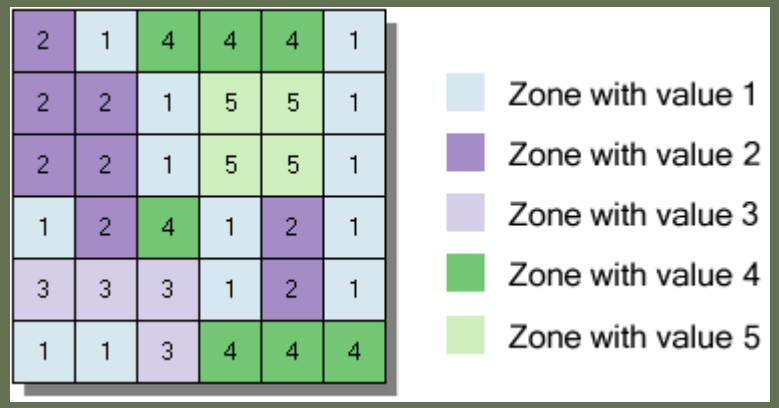
ZONES AND REGIONS

Zones

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

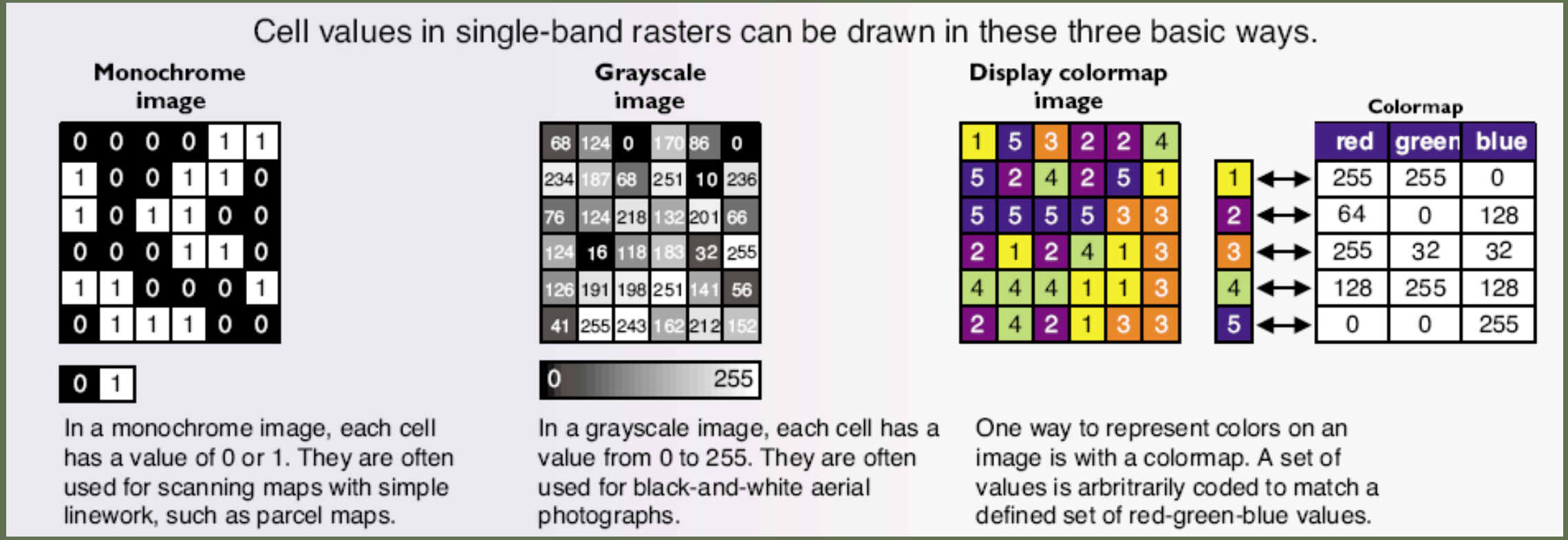
Regions

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



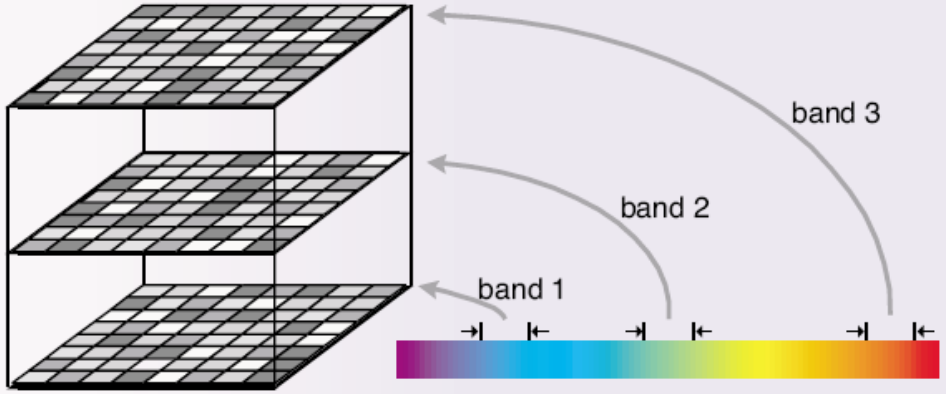
desktop.arcgis.com

SINGLE BAND RASTERS

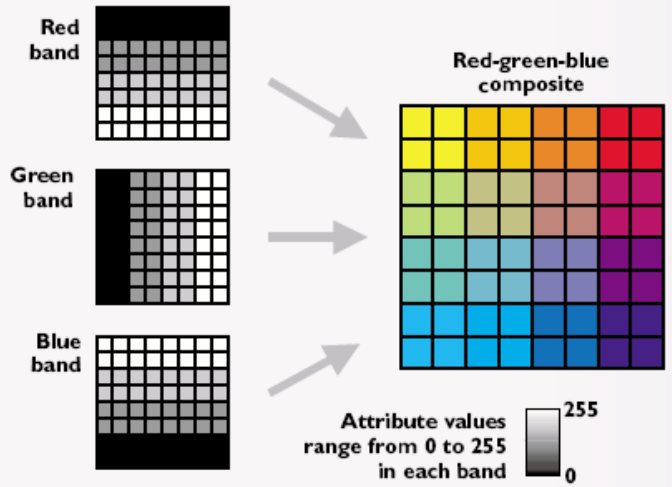


MULTIBAND RASTERS

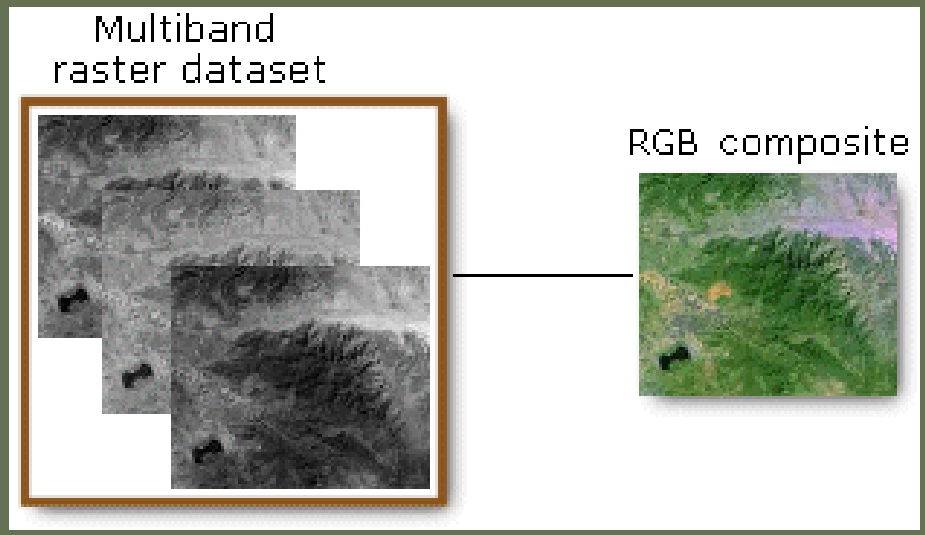
Raster datasets have one or many bands. In multiband rasters, a band represents a segment of the electromagnetic spectrum that has been collected by a sensor.



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

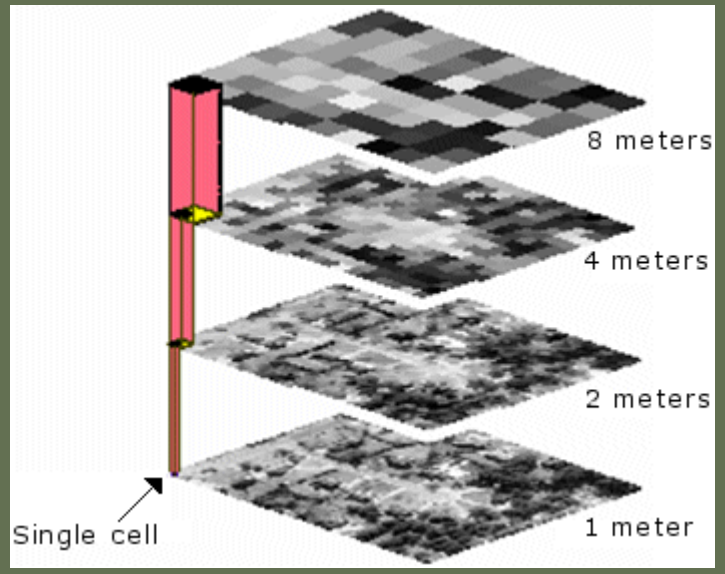


Multiband rasters are often displayed as red-green-blue composites. This band configuration is common because these bands can be directly displayed on computer displays, which employ a red-green-blue color rendition model.



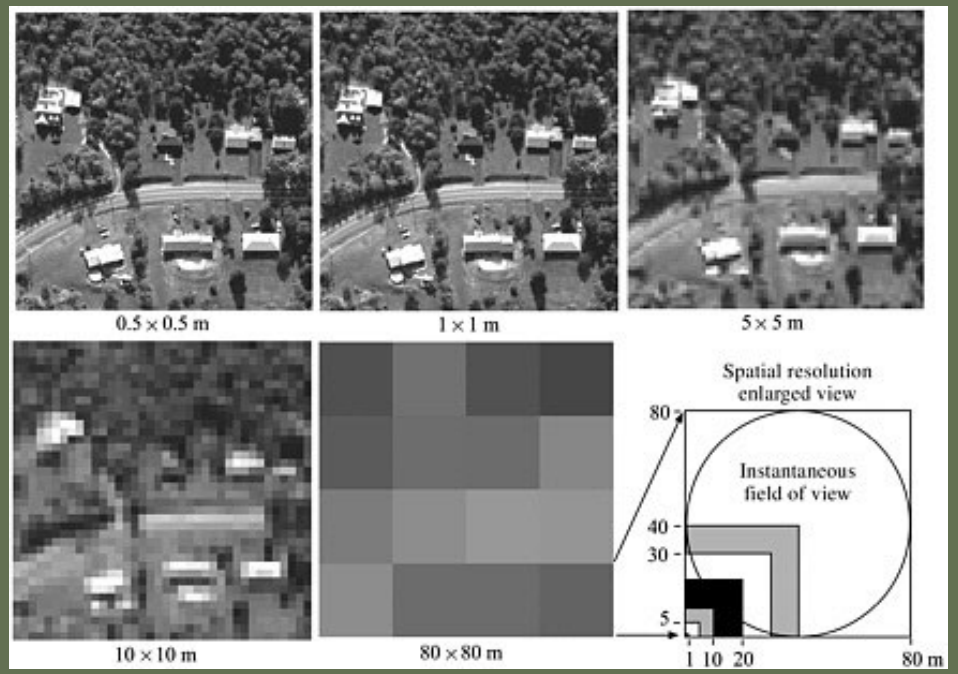
RESOLUTION

- Spatial
- Spectral
- Temporal
- Radiometric

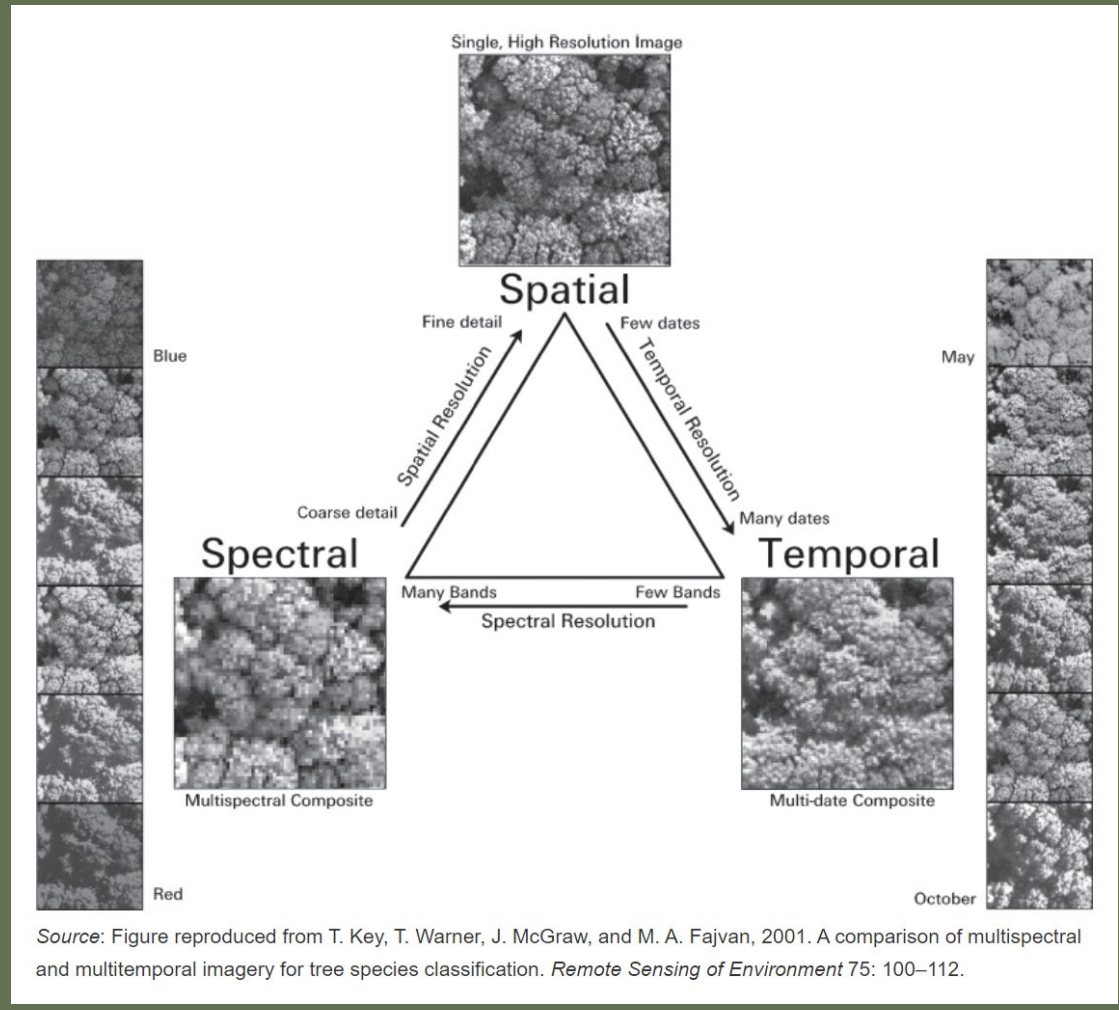


Spatial Resolution

RESOLUTION



www.nap.edu



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.

The SAGE Handbook of Remote Sensing
methods.sagepub.com

RADIOMETRIC RESOLUTION

Radiometric Resolution 8-Bit | Sentinel 2 – Tokyo Coast

Radiometric Resolution 4-Bit | Sentinel 2 – Tokyo Coast

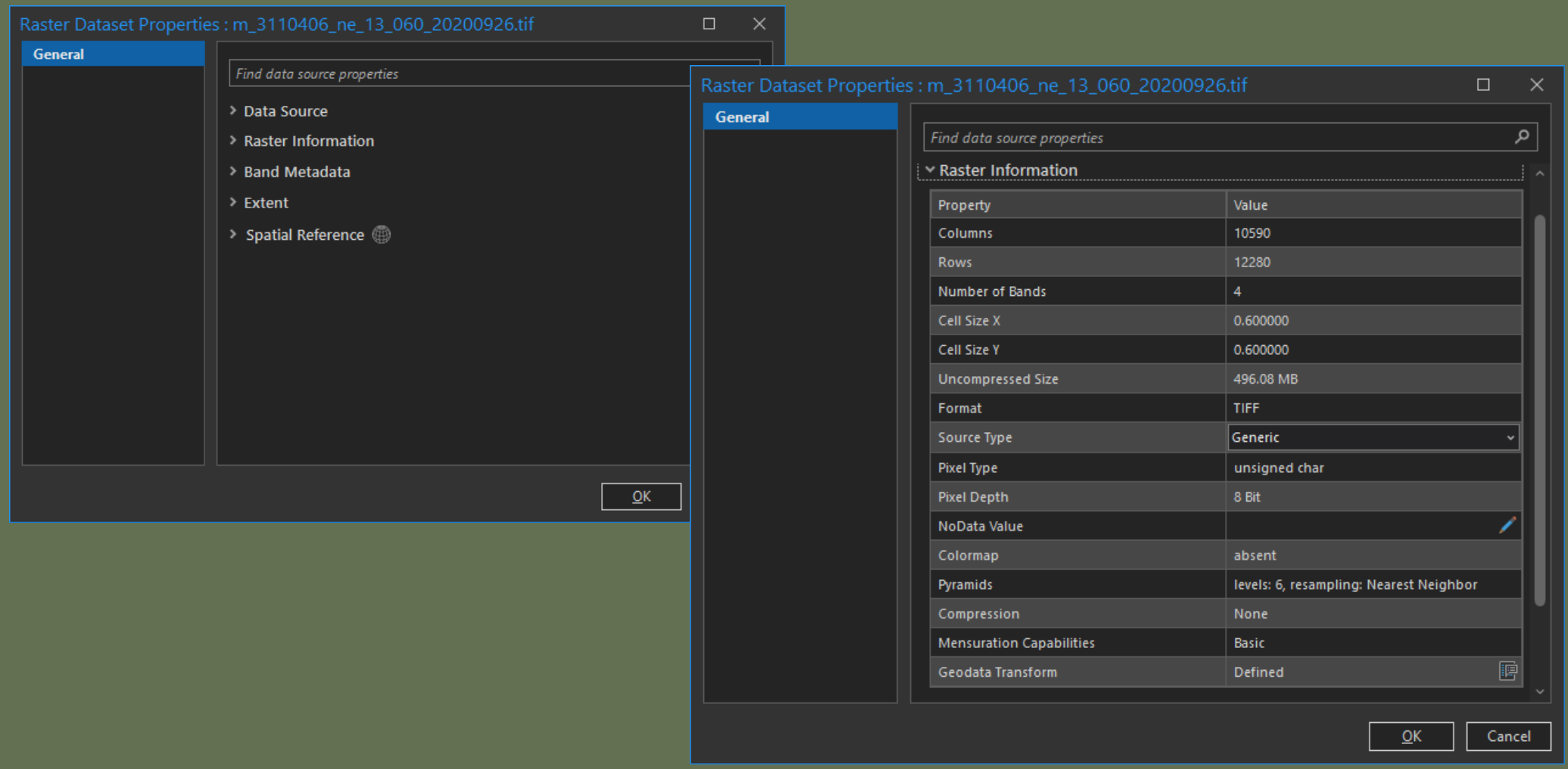
Radiometric Resolution 2-Bit | Sentinel 2 – Tokyo Coast

https://gisgeography.com/bit-depth/

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.

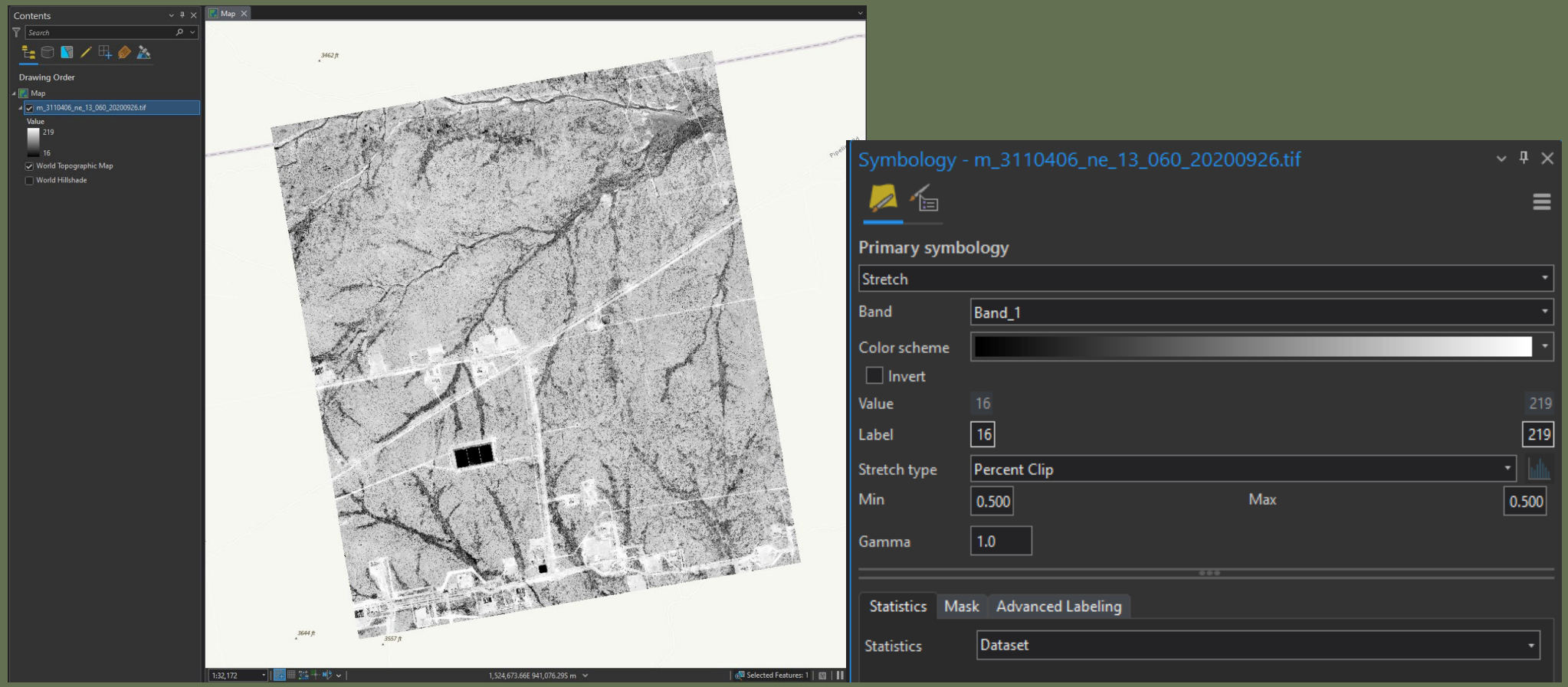
RASTER INFORMATION



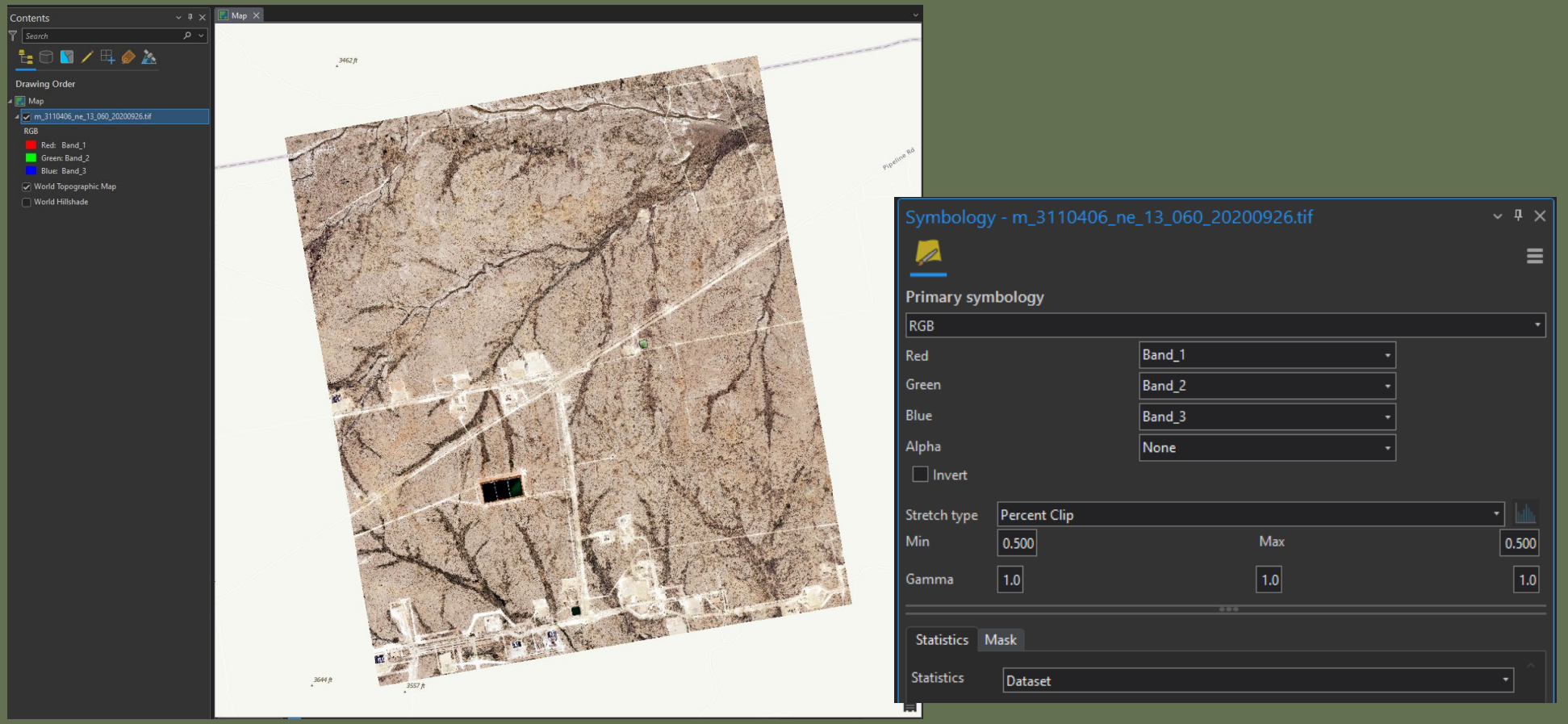
DISPLAY

- 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

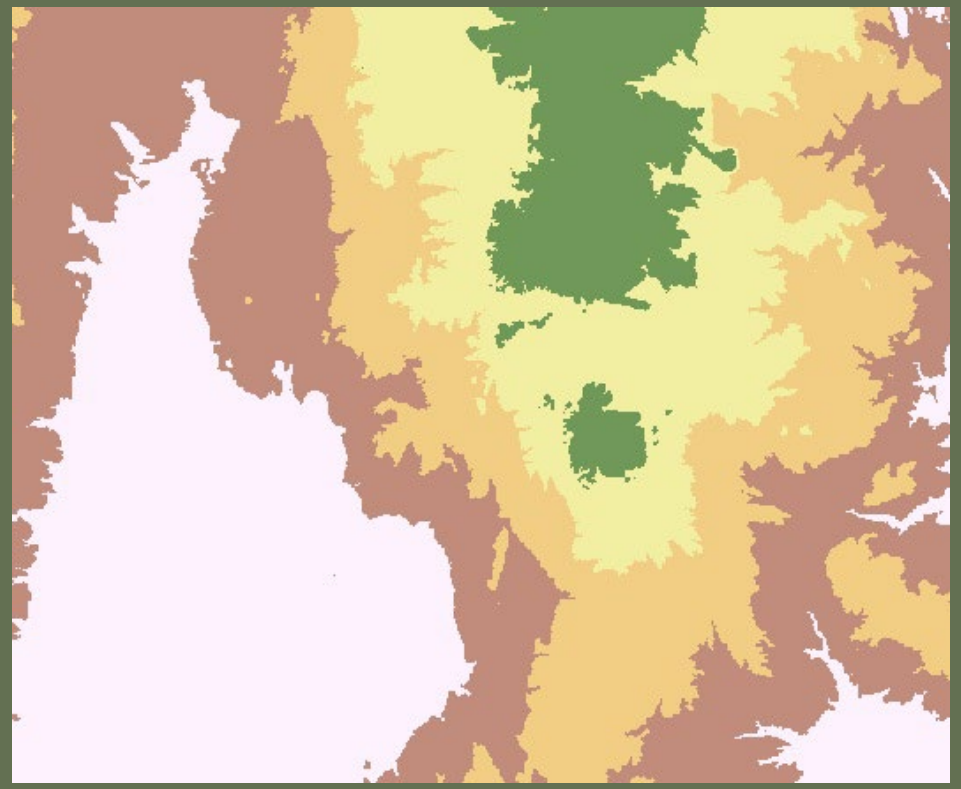
STRETCH


Contents
Search
Drawing Order
Map
m_3110406_ne_13_060_20200926.tif
Value
219
16
World Topographic Map
World Hillshade
Map
3462 ft
3644 ft
3557 ft
1:32,172
1,524,673.66E 941,076.29S m
Selected Features: 1
Symbology - m_3110406_ne_13_060_20200926.tif
Primary symbology
Stretch
Band
Band_1
Color scheme
Invert
Value
16
219
Label
16
219
Stretch type
Percent Clip
Min
0.500
Max
0.500
Gamma
1.0
Statistics
Mask
Advanced Labeling
Statistics
Dataset

RGB COMPOSITE



CLASSIFIED



Primary symbology

Classify

Field: No fields

Normalization: No fields

Method: Natural Breaks (Jenks)

Classes: 5

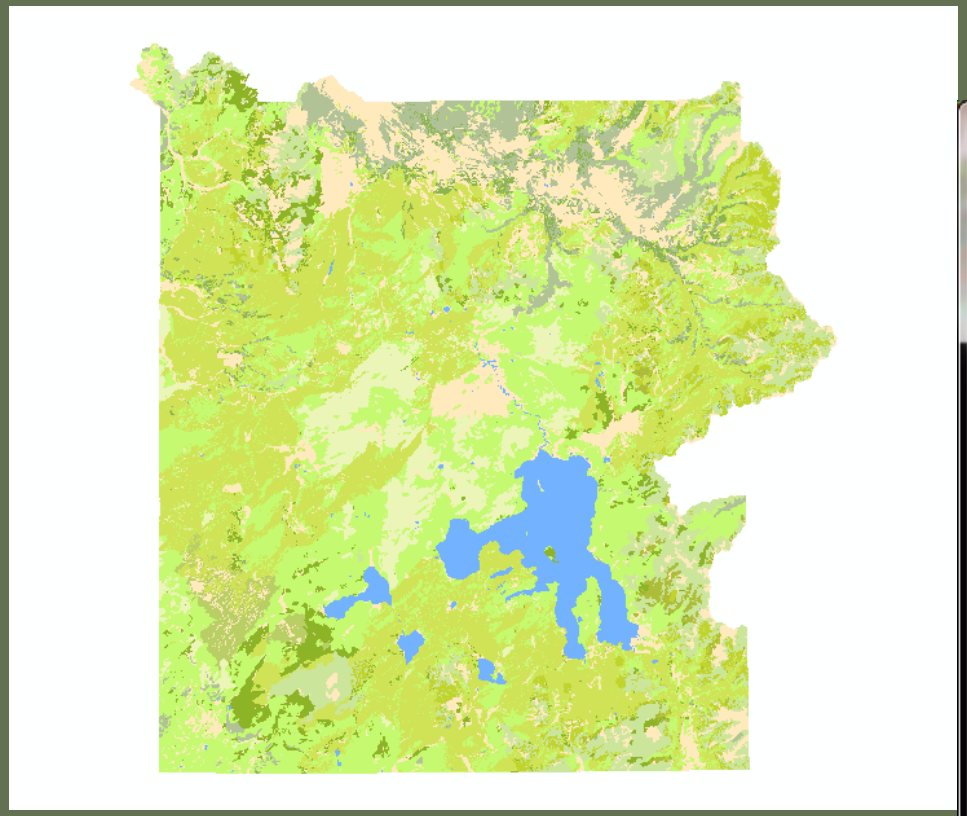
Color scheme

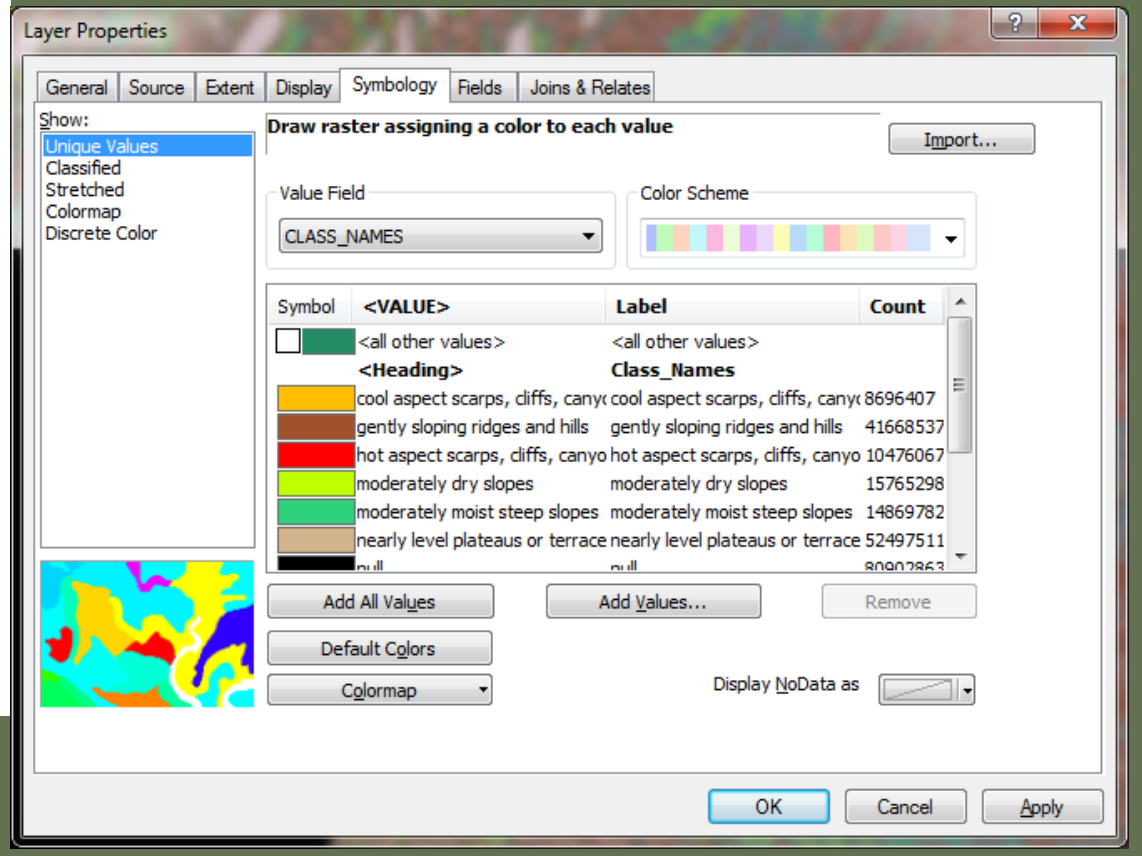
Classes | Mask | Histogram

More | + 0.0 | - 0.0

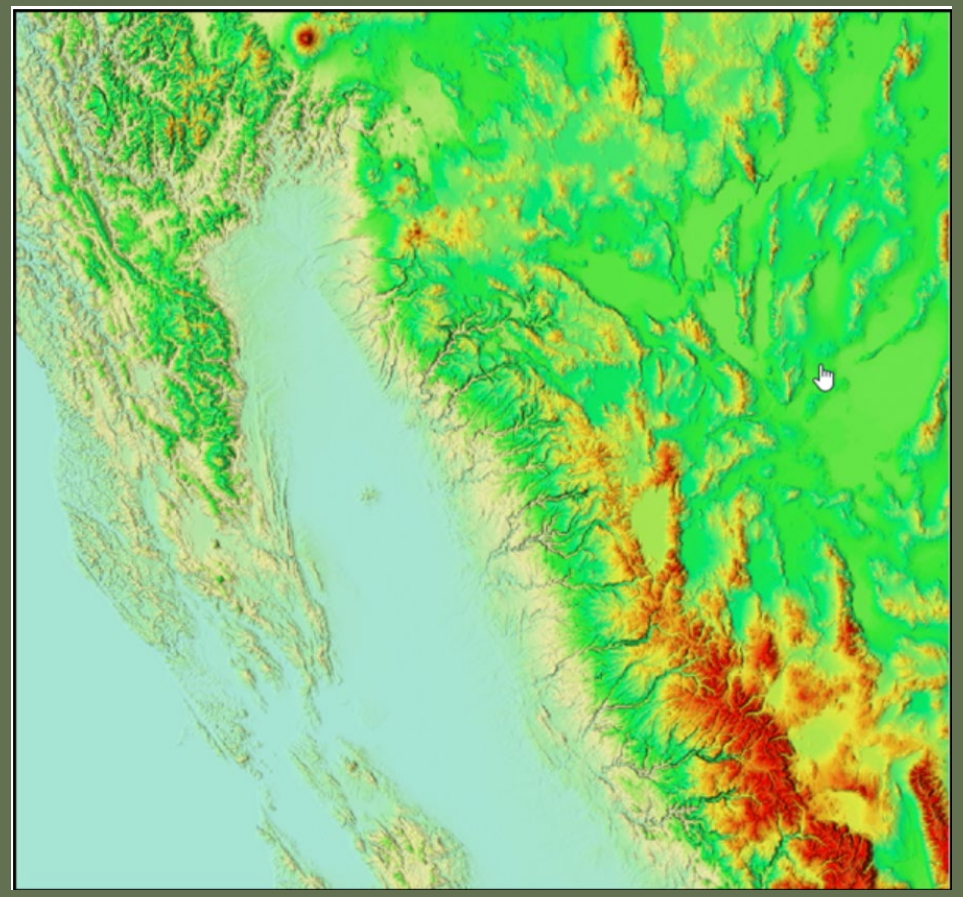
Color	Upper value	Label
	≤ 36.0	0.001 - 36
	≤ 87.0	36.001 - 87
	≤ 116.0	87.001 - 116
	≤ 139.0	116.001 - 139
	≤ 254.0	139.001 - 254

UNIQUE VALUES





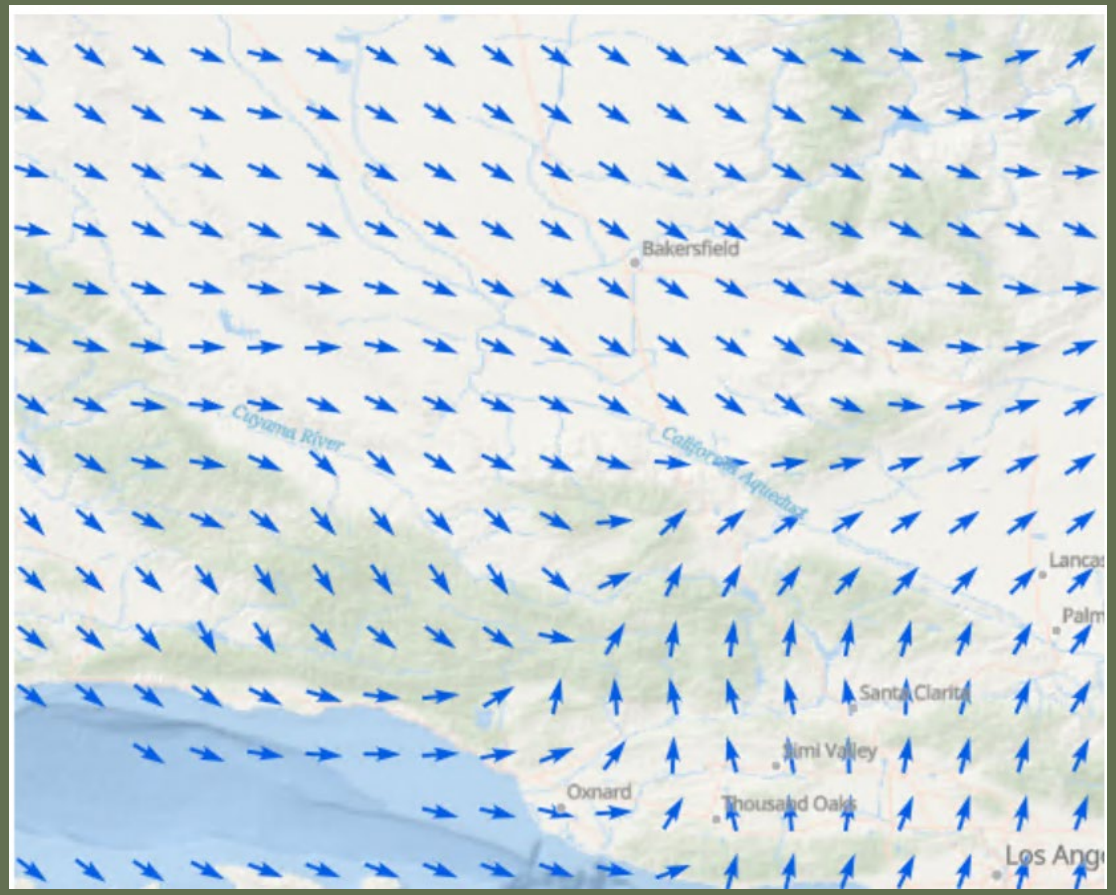
SHADED RELIEF



pro.arcgis.com

- Can choose color scheme and illumination source for hill shade

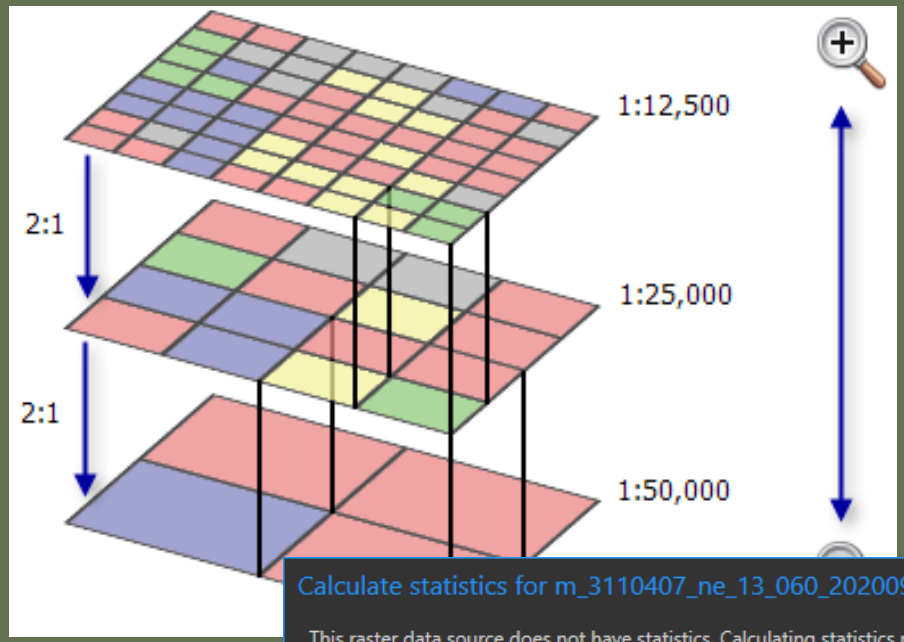
VECTOR FIELD

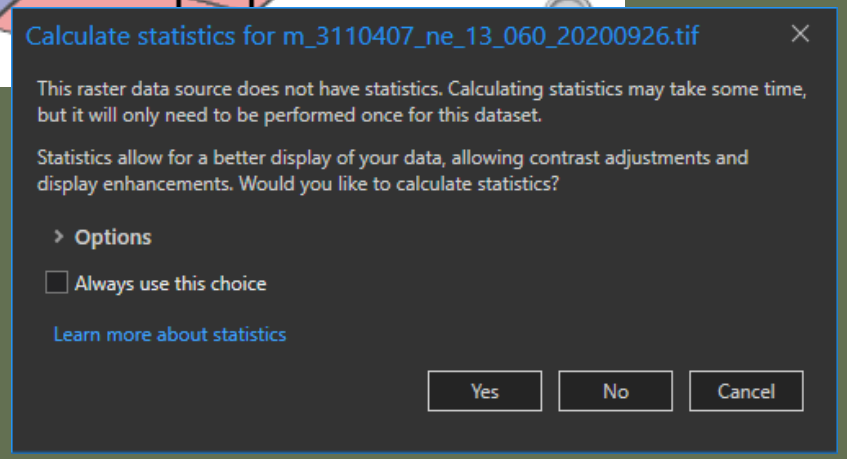


pro.arcgis.com

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





COMPRESSION

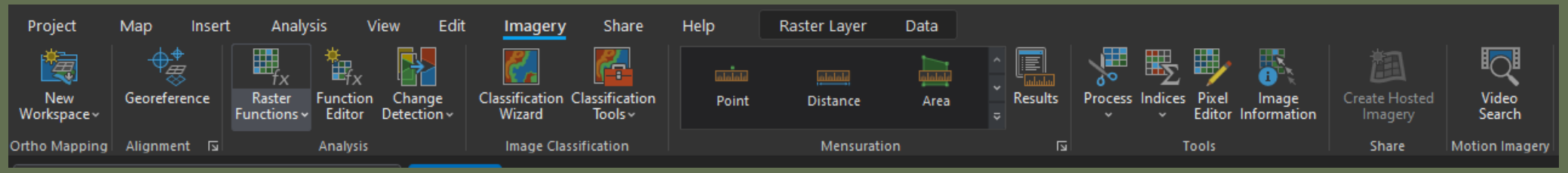
- Reduces file size
- Requires better CPU capabilities to decompress
- Possibly low resolution output
- Techniques: Transmission, Storage
- Types:
  - Lossy – JPEG, JPEG 2000
  - Lossless – LZW, LZ77, PackBits

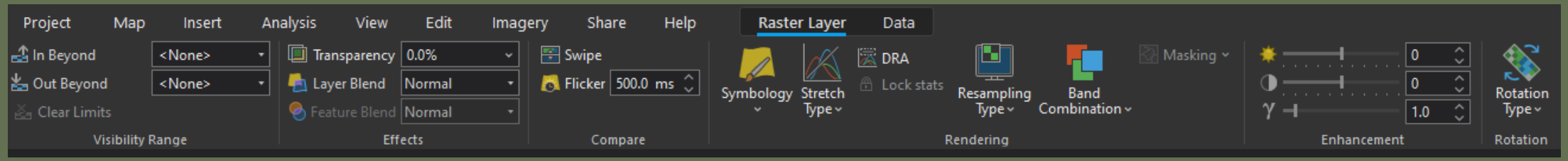
PROJECTION

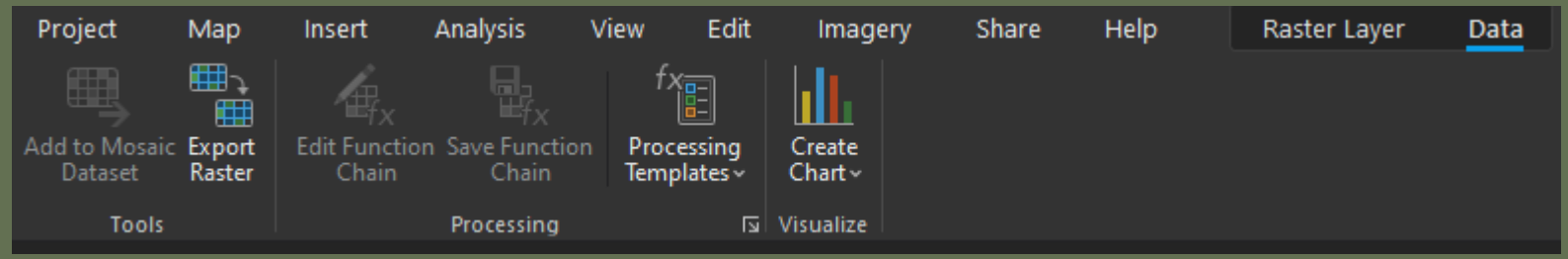
- Defining spatial reference system for a raster dataset will have an effect on the cells, as they are permanently resampled to fit this projection.
- Defining spatial reference system for a mosaic dataset does not effect cells but the projection is used to create the footprints, boundaries, or other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

ANALYSIS & PROCESSING

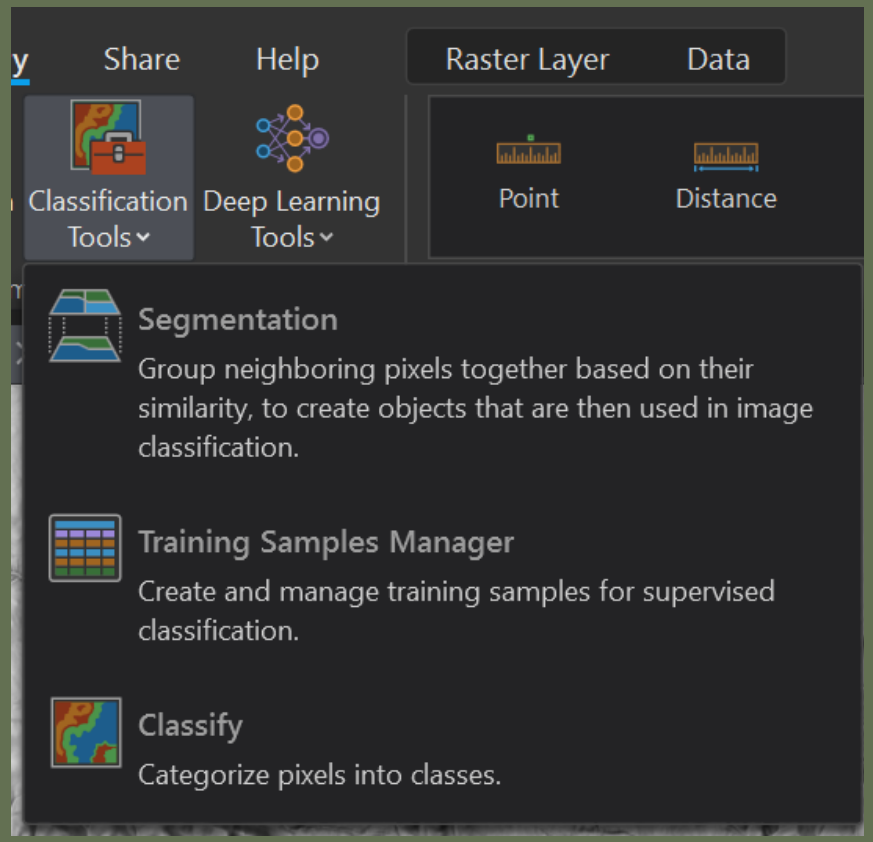
IMAGE ANALYSIS TOOLS

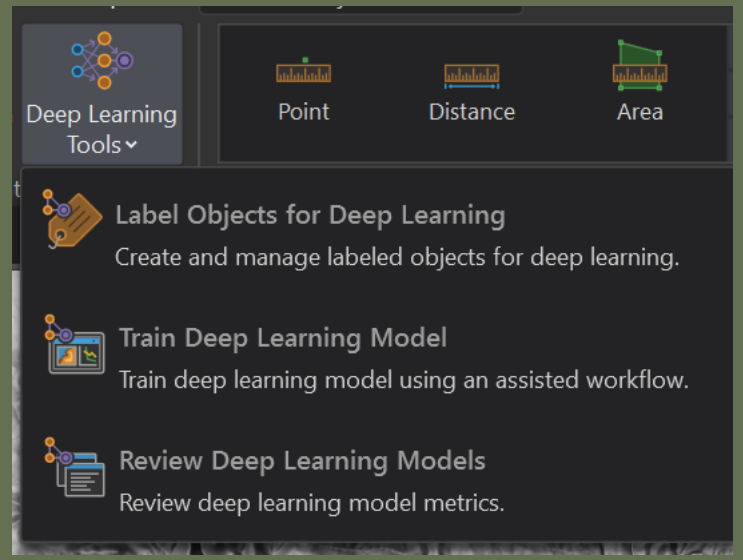


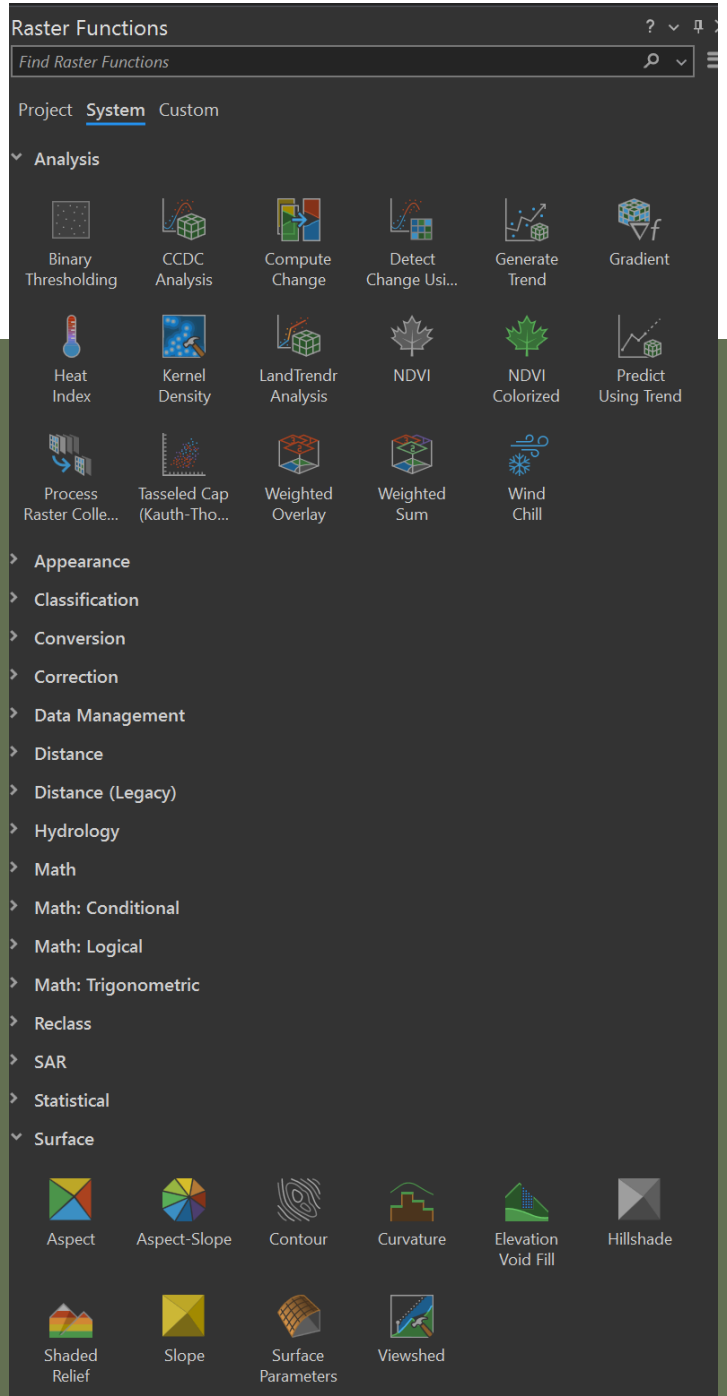




RASTER FUNCTIONS







RASTER FUNCTIONS VS GEOPROCESSING TOOLS

Geoprocessing Tools

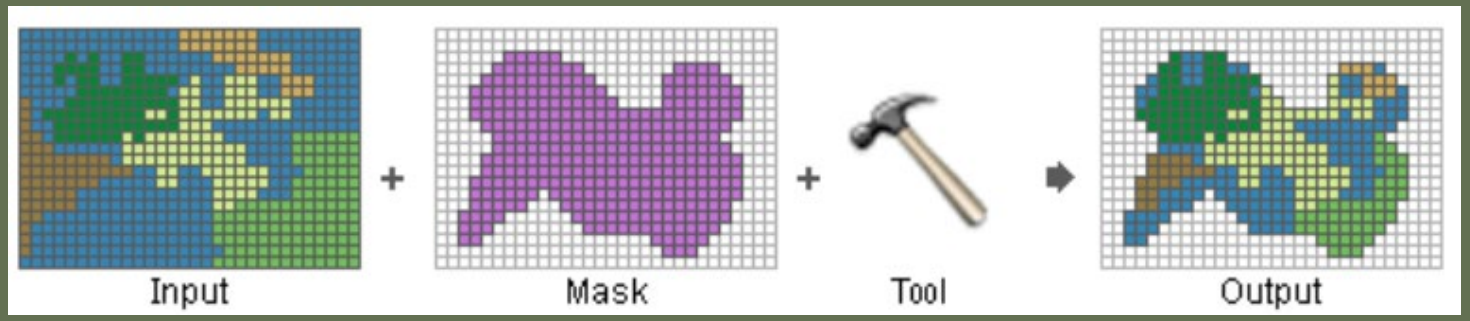
- Creates new data on disk
- Can view and edit geoprocessing history
- Can batch process
- Can combine processes for complex modeling
- …

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.



pro.arcgis.com

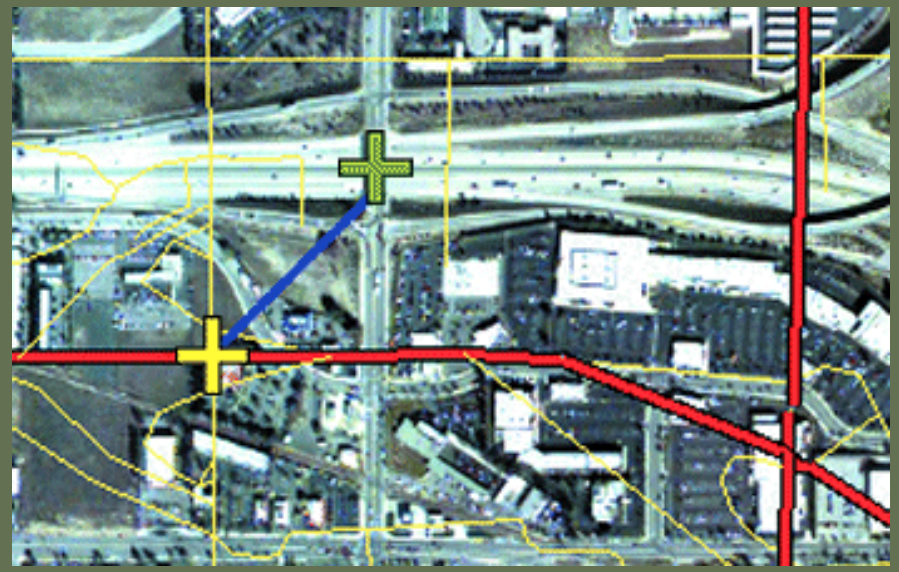
GEOREFERENCING

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.

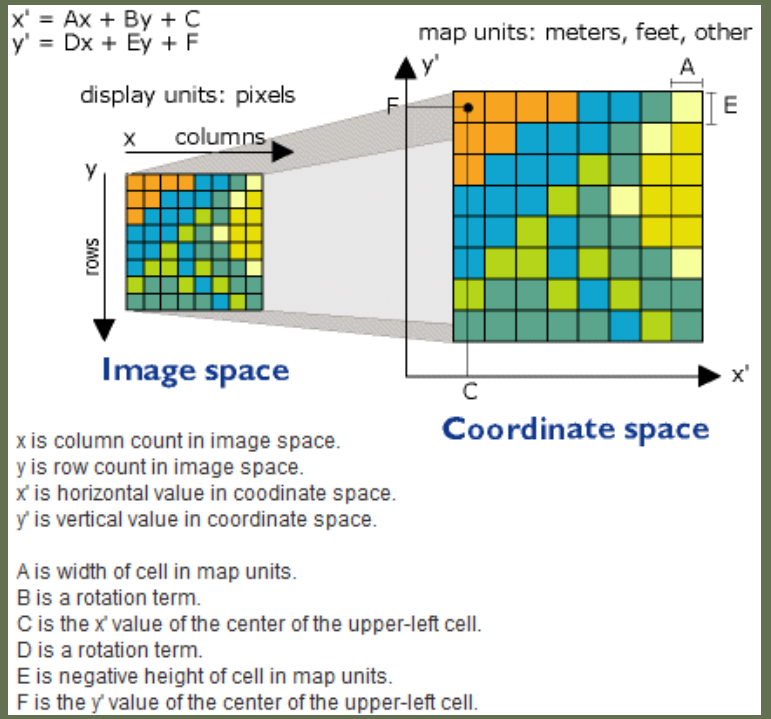


HOW MANY CONTROL POINTS?

- 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.

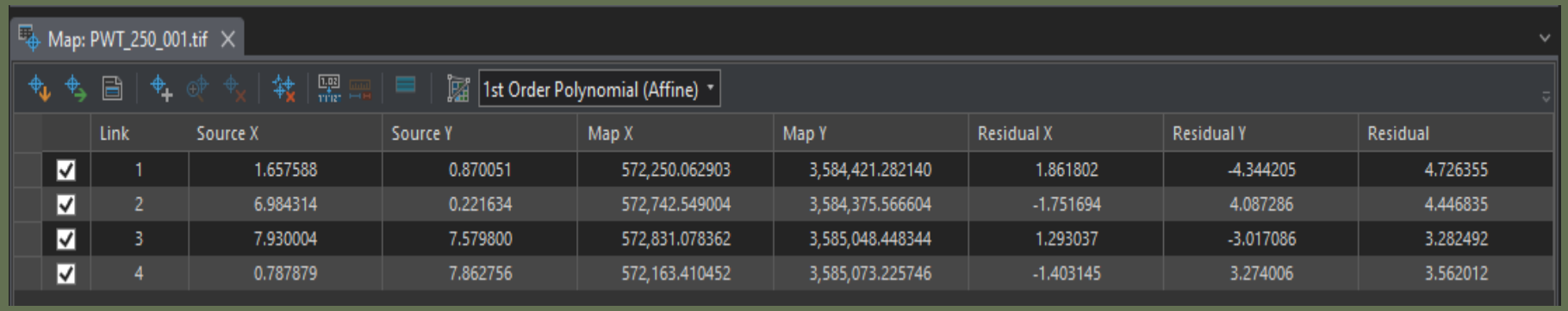
TRANSFORMATION

- 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, 1st, 2nd, 3rd or Zero order)
  - Spline
  - Adjust
  - Projective Transformation

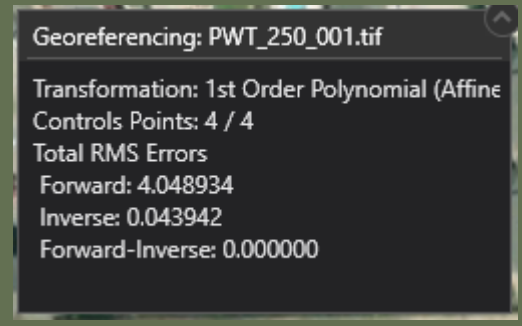


ROOT MEAN SQUARE ERROR (RMSE)

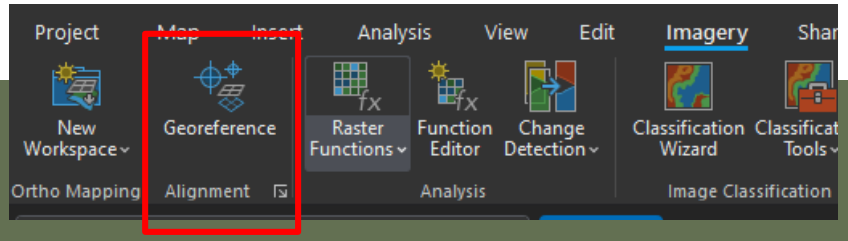
- Distance measuring concept to compare expected with measured data.
- The error is the difference between where the from point ended up as opposed to the actual location that was specified.
- The total error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS 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.

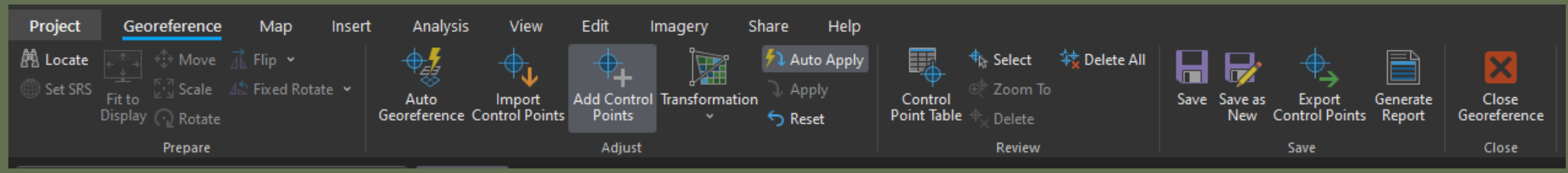


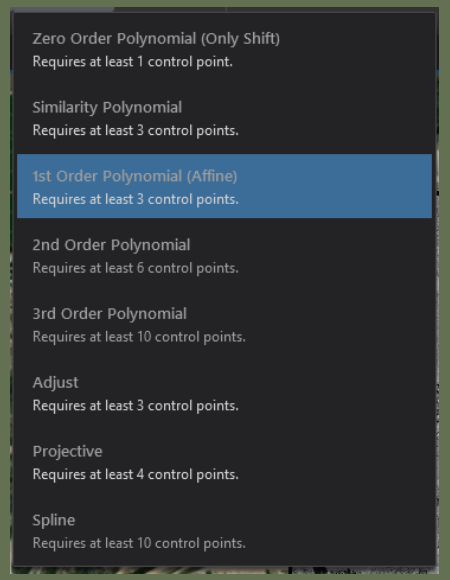
Link	Source X	Source Y	Map X	Map Y	Residual X	Residual Y	Residual
1	1.657588	0.870051	572,250.062903	3,584,421.282140	1.861802	-4.344205	4.726355
2	6.984314	0.221634	572,742.549004	3,584,375.566604	-1.751694	4.087286	4.446835
3	7.930004	7.579800	572,831.078362	3,585,048.448344	1.293037	-3.017086	3.282492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



TOOLS


Project
Map
Insert
Analysis
View
Edit
Imagery
Shar
New Workspace
Georeference
Raster Functions
Function Editor
Change Detection
Classification Wizard
Classificat Tools
Ortho Mapping
Alignment
Analysis
Image Classification


Project
Georeference
Map
Insert
Analysis
View
Edit
Imagery
Share
Help
Locate
Set SRS
Fit to Display
Move
Scale
Rotate
Flip
Fixed Rotate
Prepare
Auto Georeference
Import Control Points
Add Control Points
Transformation
Auto Apply
Apply
Reset
Adjust
Control Point Table
Select
Zoom To
Delete
Delete All
Review
Save
Save as New
Export Control Points
Generate Report
Save
Close Georeference
Close


Zero Order Polynomial (Only Shift)
Requires at least 1 control point.
Similarity Polynomial
Requires at least 3 control points.
1st Order Polynomial (Affine)
Requires at least 3 control points.
2nd Order Polynomial
Requires at least 6 control points.
3rd Order Polynomial
Requires at least 10 control points.
Adjust
Requires at least 3 control points.
Projective
Requires at least 4 control points.
Spline
Requires at least 10 control points.

SAVING GEOREFERENCED RASTER

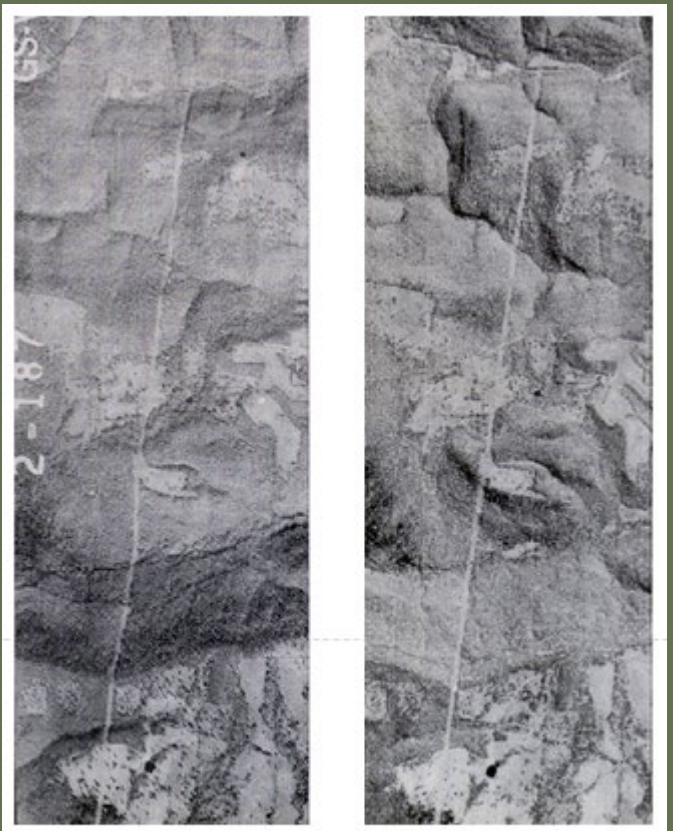
- Save as New – permanently transforms your raster dataset (creates new dataset)
- Save – stores transformation information in auxiliary files

- 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

ORTHORECTIFYING

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.



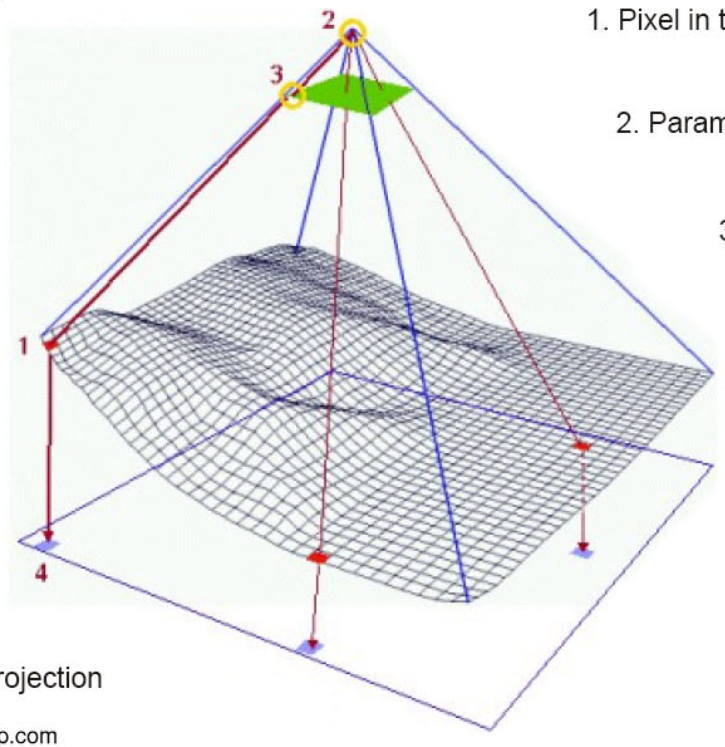
Above are 2 images of the same geographic area. Note the road that passes through the mountains. In the left "raw" or unrectified image, the road appears to be crooked when in fact it is not. The image on the right has been rectified image and the road appears planimetrically correct.

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

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