Image from NASA:
https://commons.wikimedia.org/wiki/File:Earth_Western_Hemisphere_transparent_background.png#filelinks

GIScience

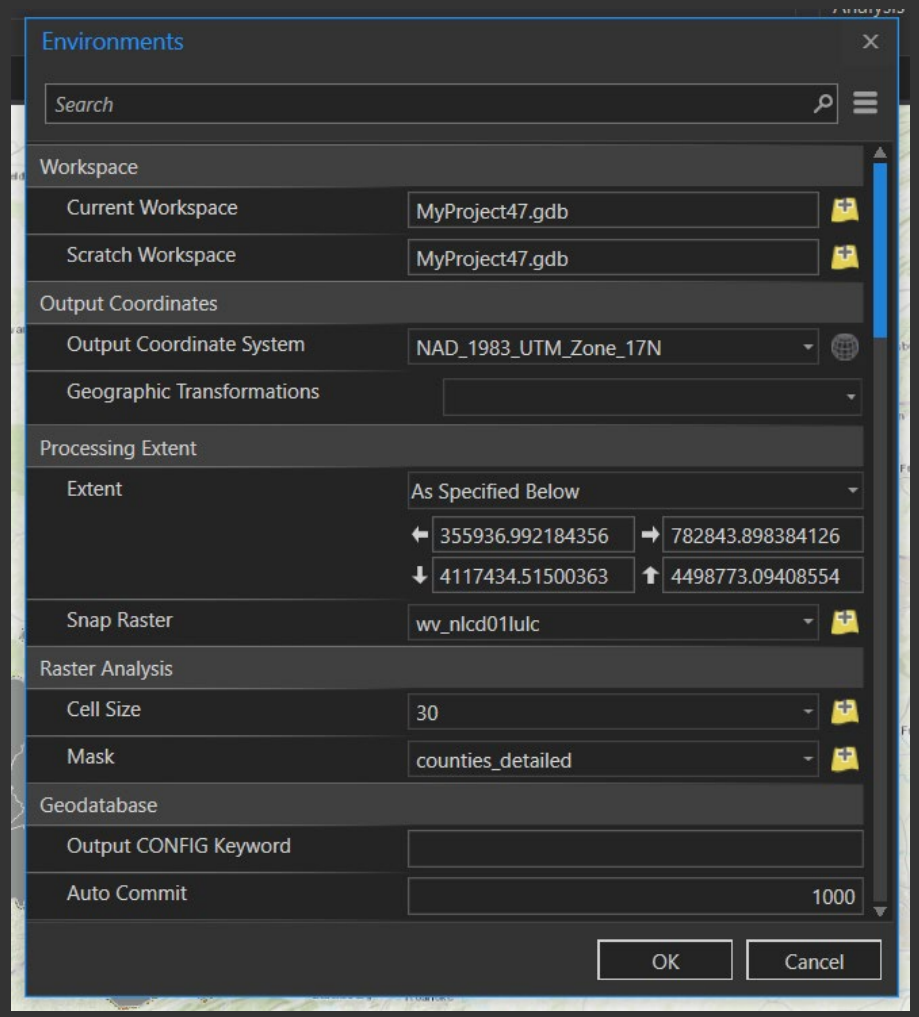
Raster Analysis

WV VIEW

AmericaView℠
Empowering Earth Observation Education
AmericaView.org - Est. 2003

Environments

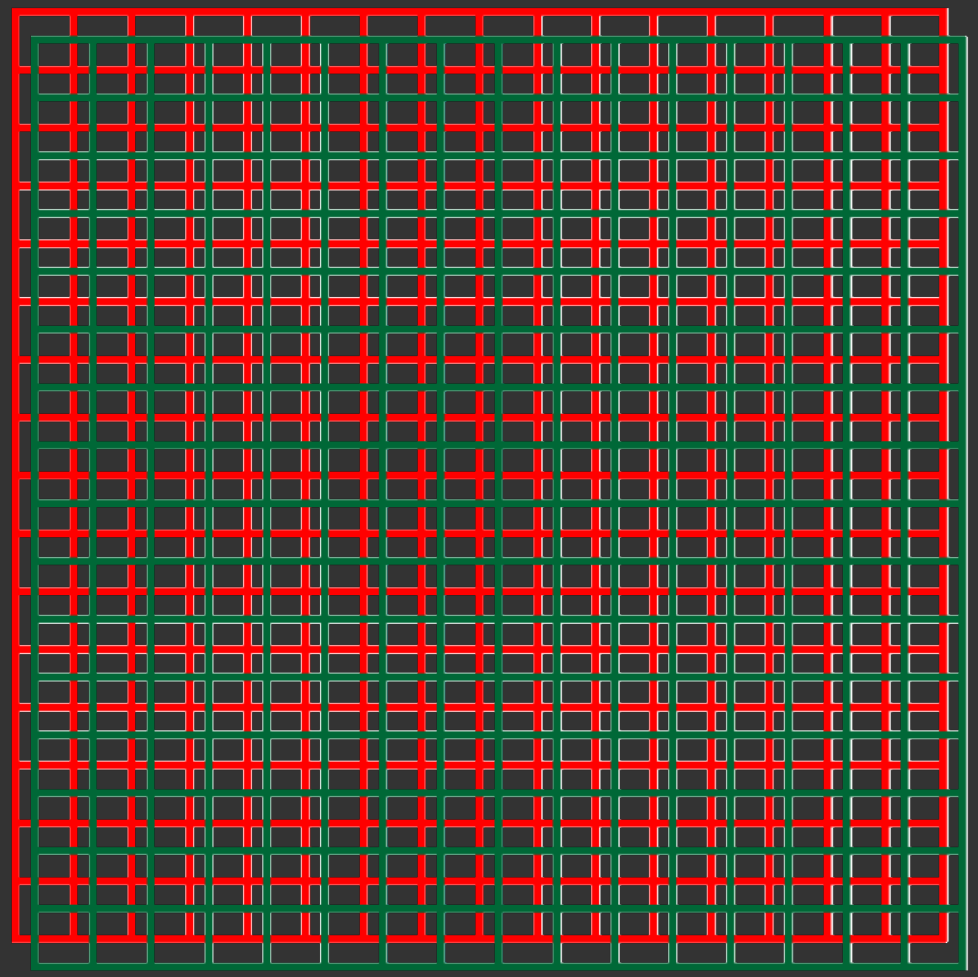
Environment Settings



- Current Workspace
- Scratch Workspace
- Output Coordinate System
- Processing Extent
- Snap Raster
- Cell Size
- Mask

Snap Raster

- Makes sure output grid aligns with the selected snap raster



Extraction and Mosaic

Extraction Methods

- Extract by Circle = extract cells that fall into a circle that is defined by a center coordinate and radius
- Extract by Mask = extract cells that fall within a raster or polygon mask
- Extract by Point = extract cells at point locations
- Extract by Polygon = extract cells that fall within the extent of a polygon as defined by its vertices
- Extract by Rectangle = extract cells that fall within a rectangular extent

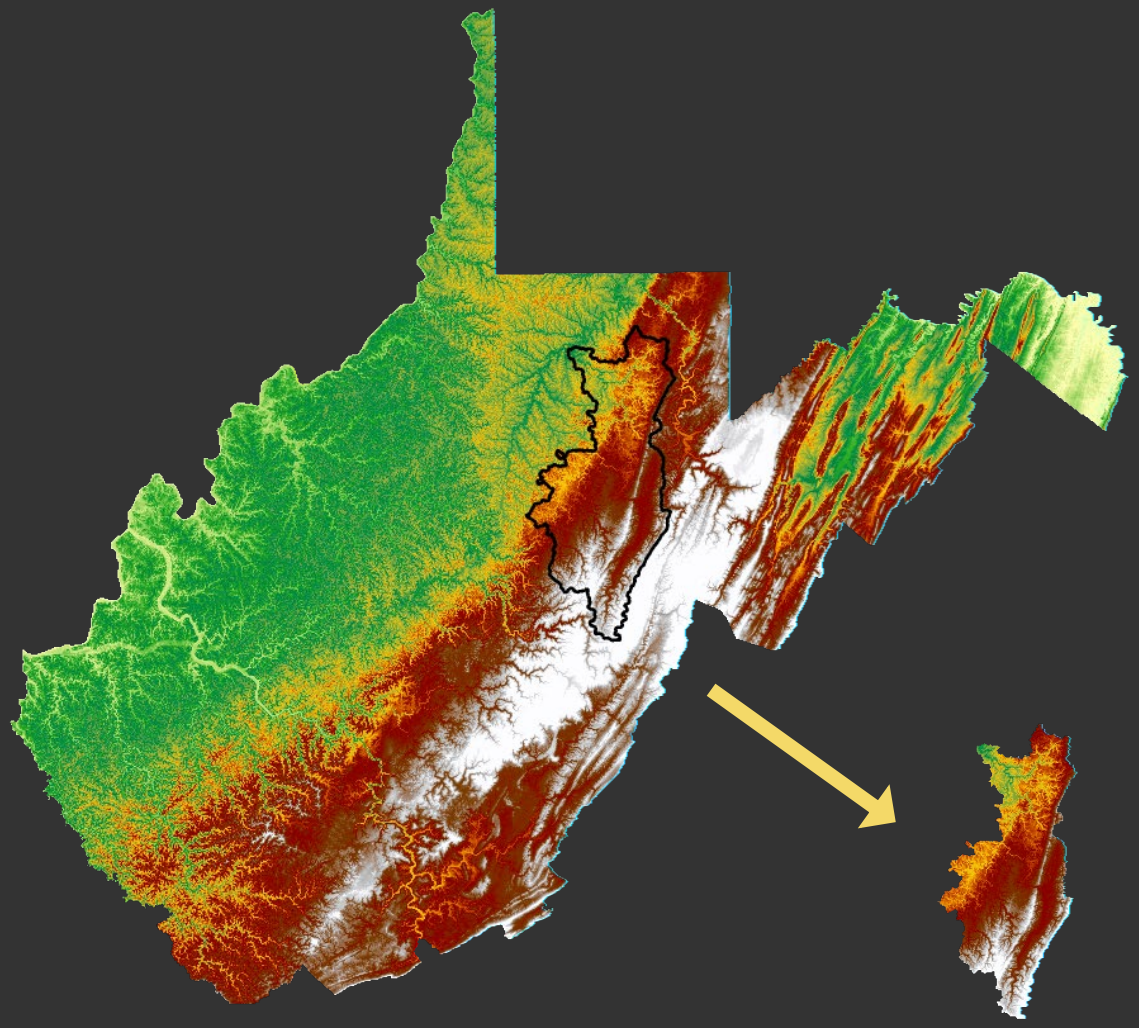
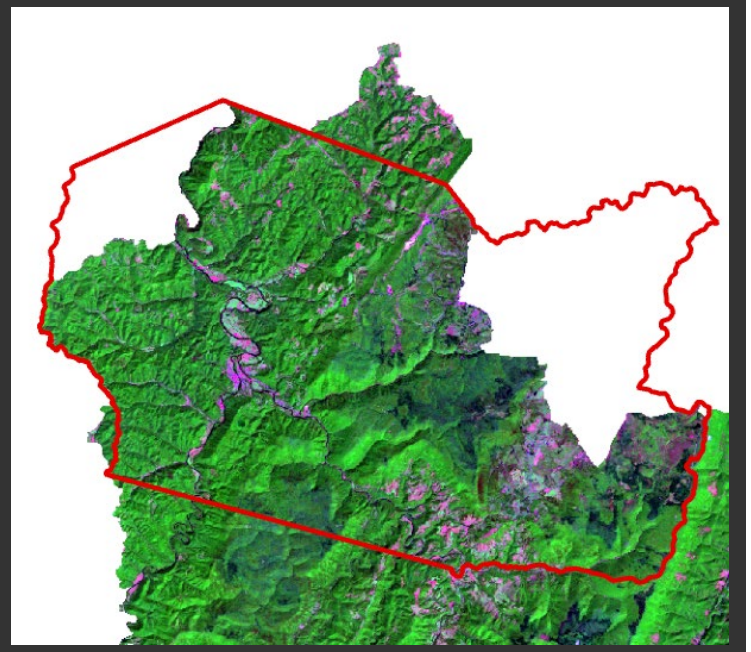
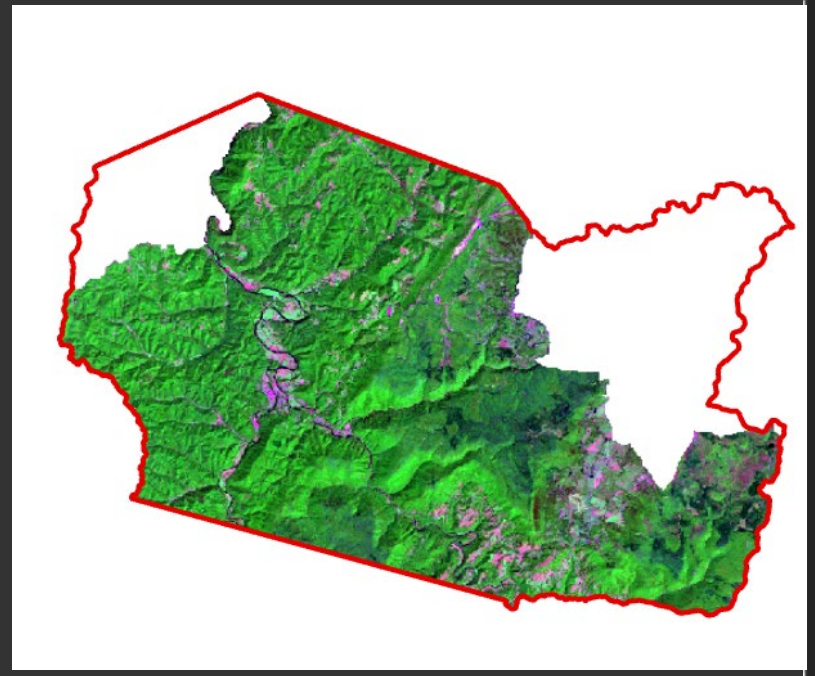
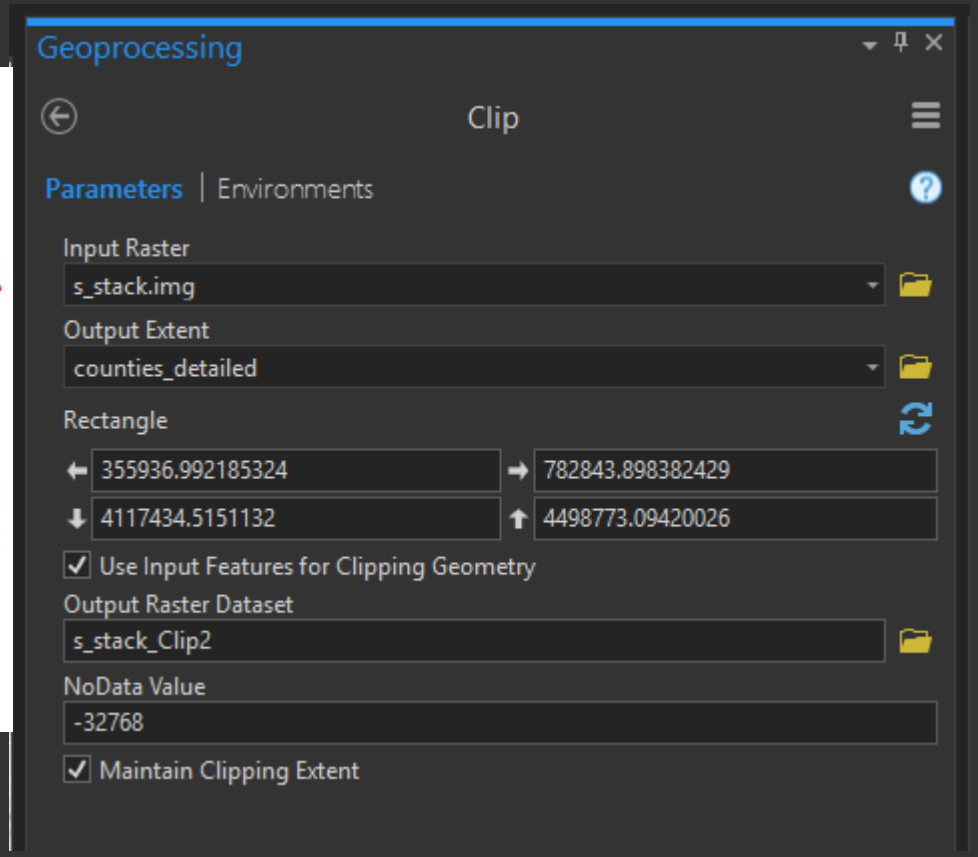


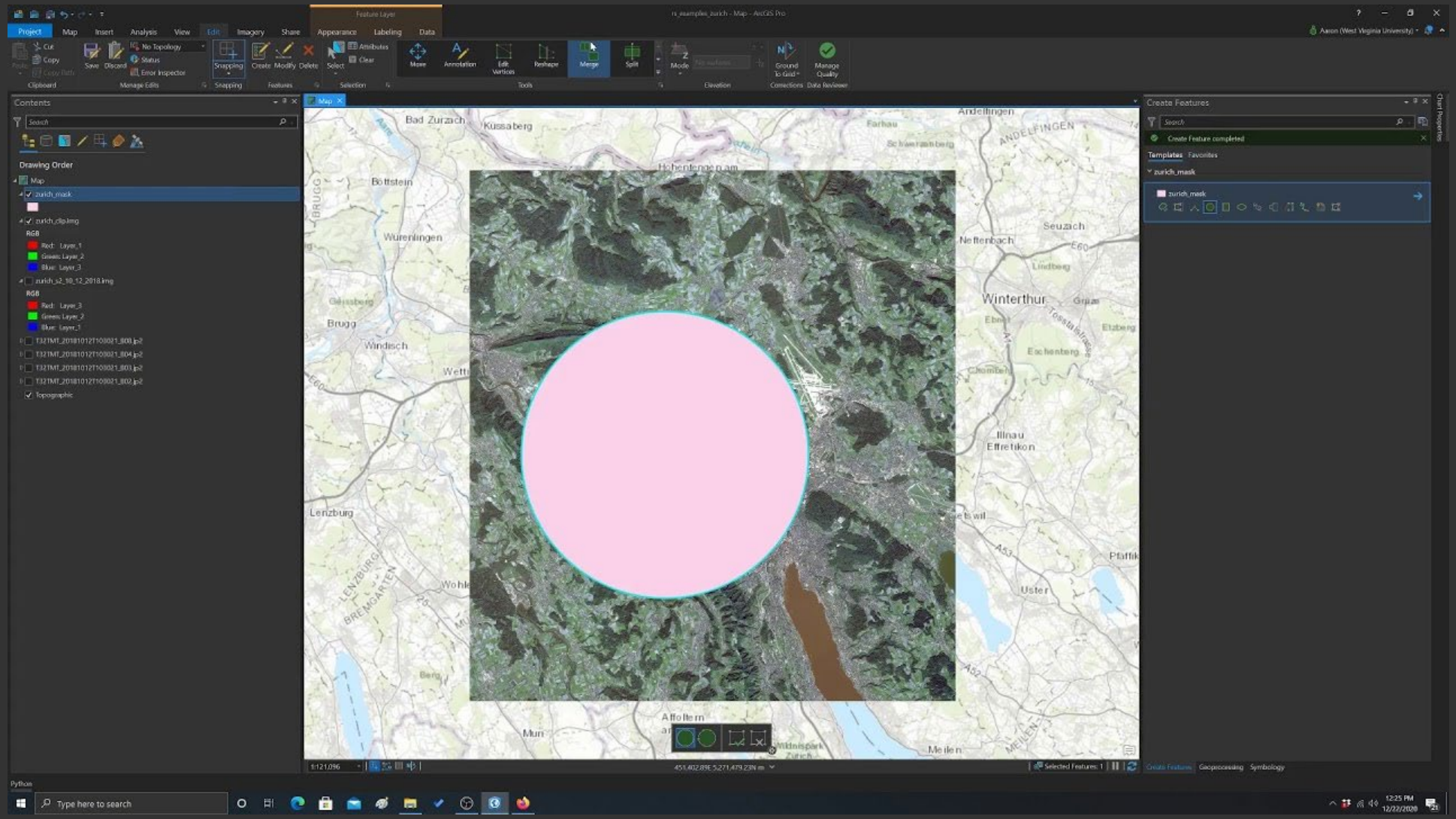
Image Clip Tool in ArcGIS Pro



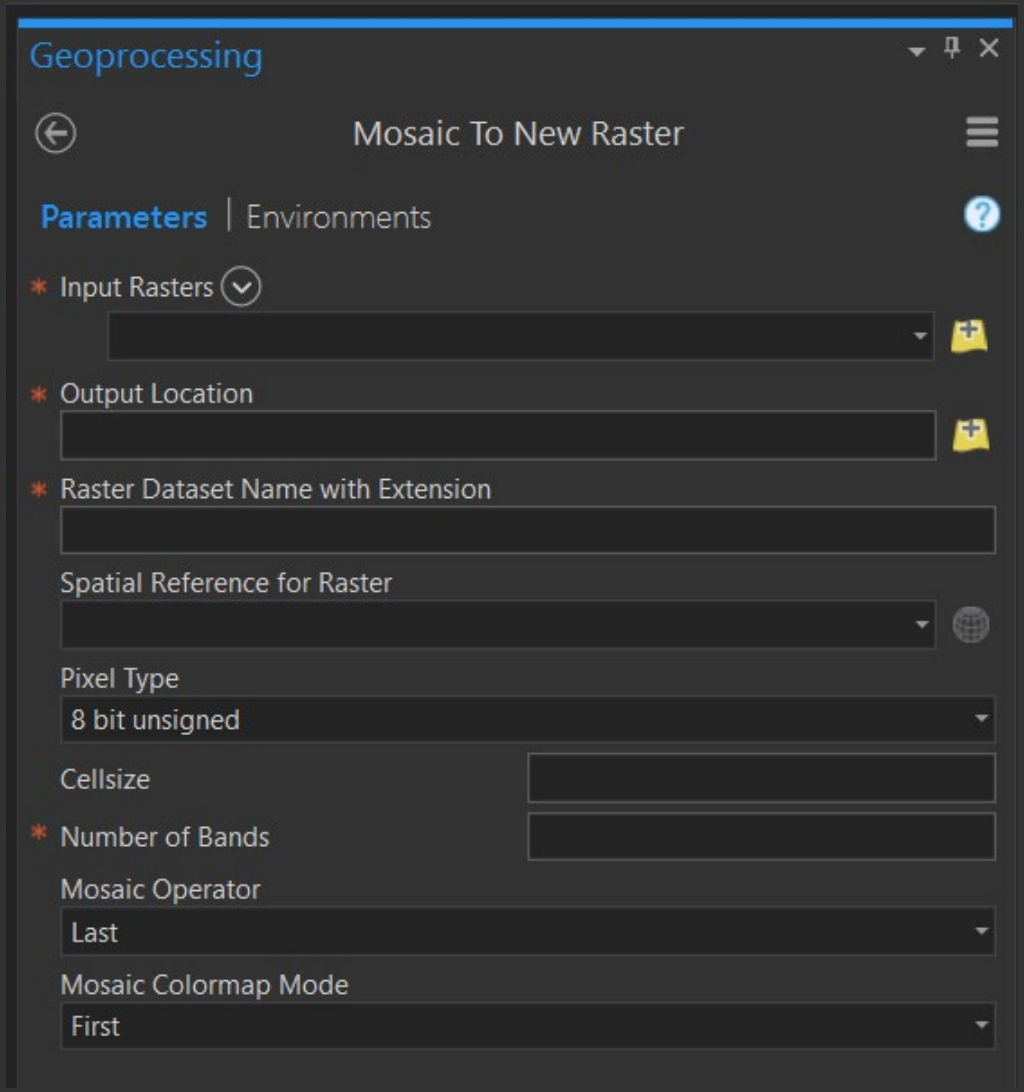




Video: Raster Clip ArcGIS Pro



Mosaic to New Raster



- Combine single band or multiband raster grids into a single raster
- Can be used for all types or raster grids, including images
- Must specify file extension, pixel type, cell size, and number of bands

Mosaic to New Raster

Assigning values at overlapping locations:

FIRST = The output cell value of the overlapping areas will be the value from the first raster dataset mosaicked into that location.

LAST = The output cell value of the overlapping areas will be the value from the last raster dataset mosaicked into that location. This is the default.

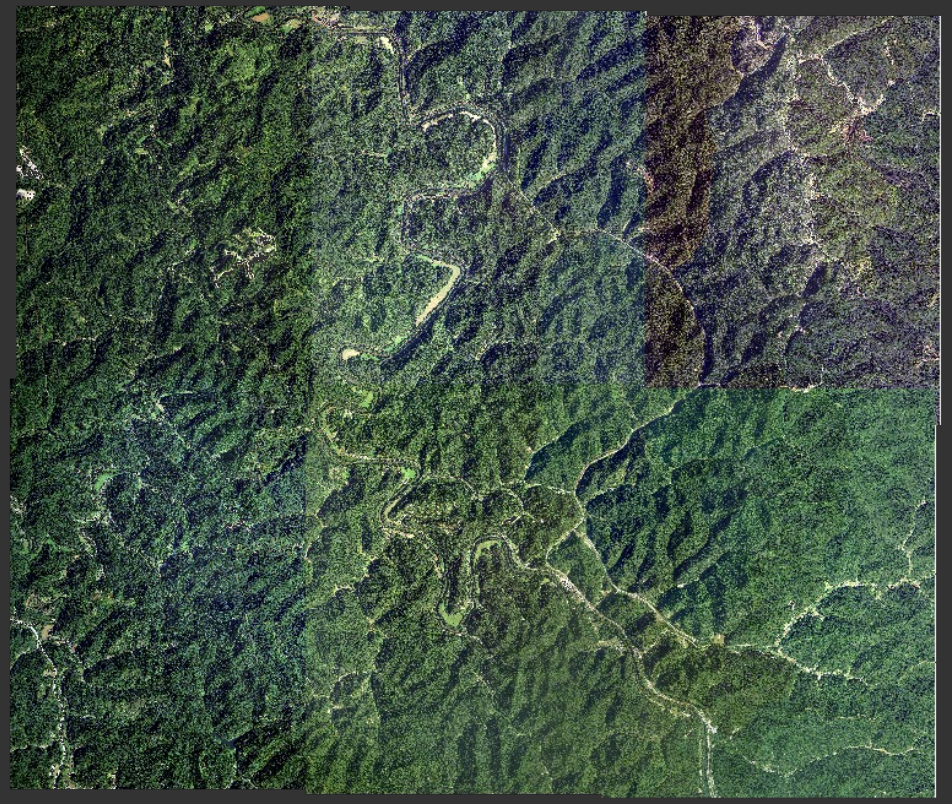
BLEND = The output cell value of the overlapping areas will be a horizontally weighted calculation of the values of the cells in the overlapping area.

MEAN = The output cell value of the overlapping areas will be the average value of the overlapping cells.

MINIMUM = The output cell value of the overlapping areas will be the minimum value of the overlapping cells.

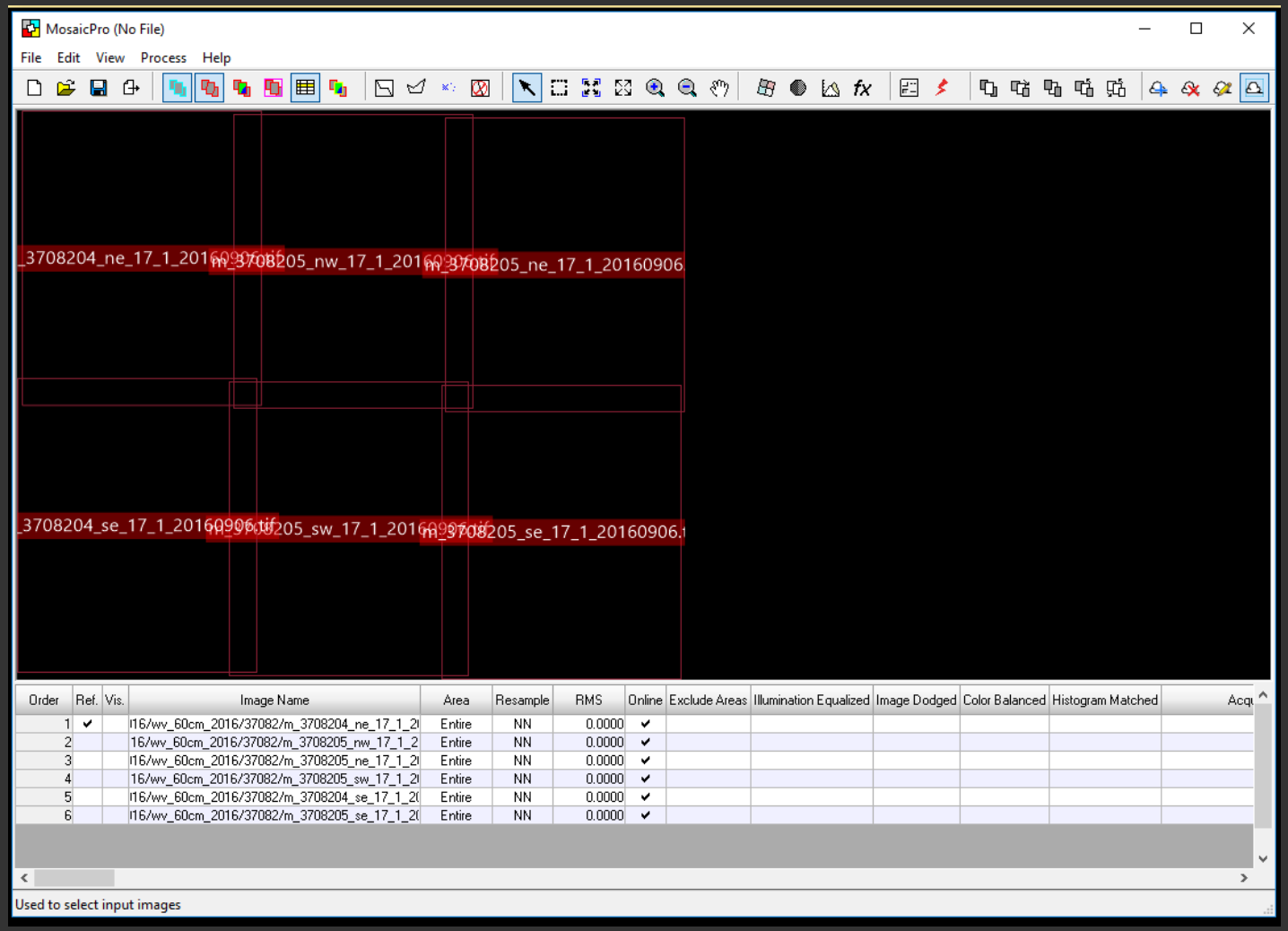
MAXIMUM = The output cell value of the overlapping areas will be the maximum value of the overlapping cells.

SUM = The output cell value of the overlapping areas will be the total sum of the overlapping cells.



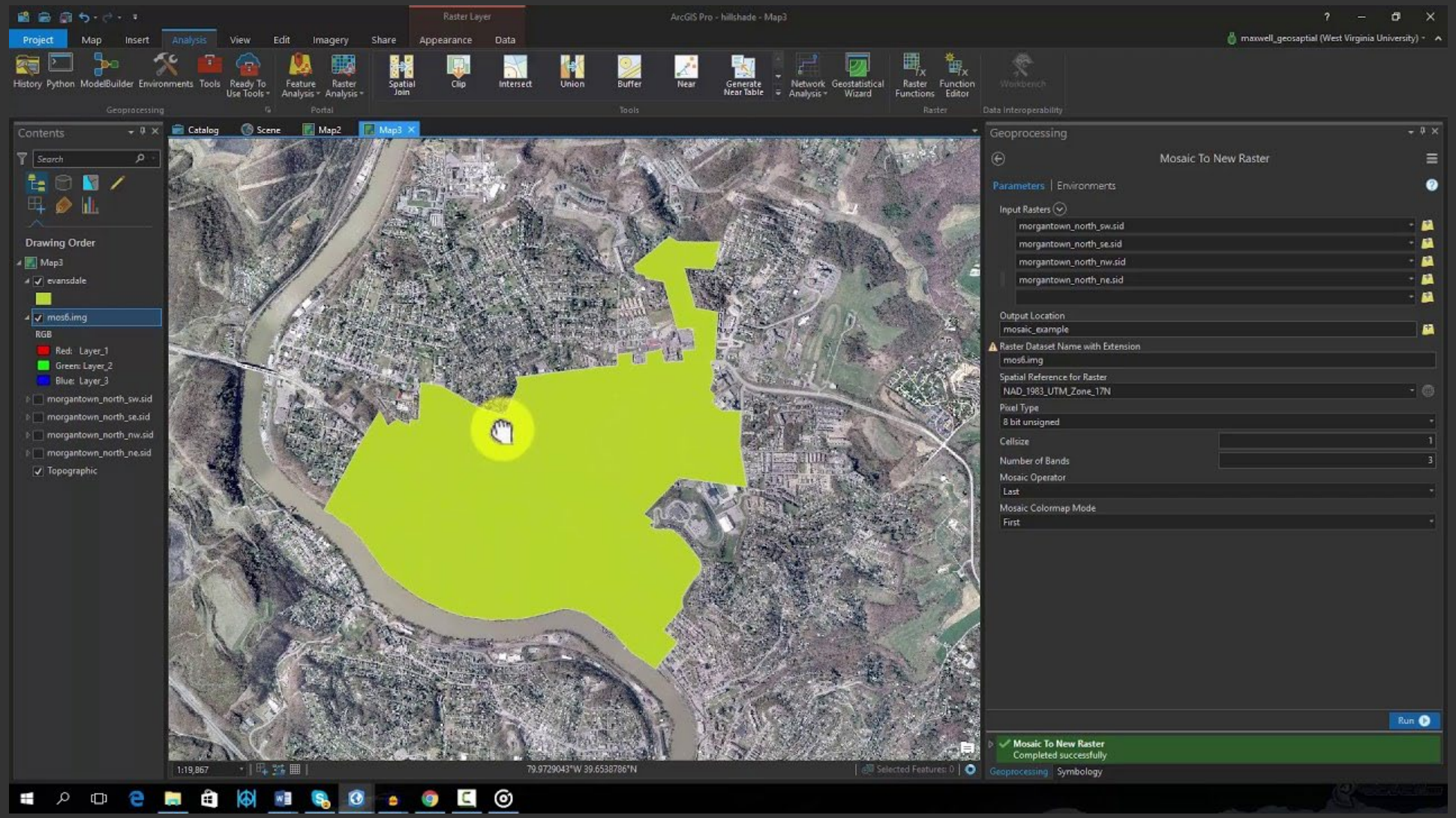
NAIP Orthophotography

Mosaic Outside of ArcGIS



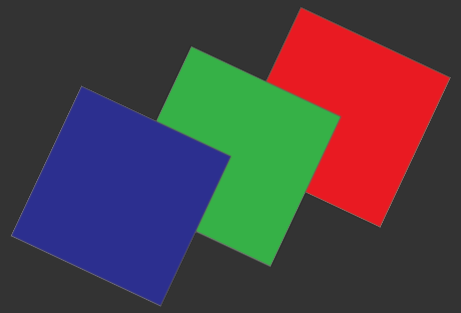
Order	Ref.	Vis.	Image Name	Area	Resample	RMS	Online	Exclude Areas	Illumination Equalized	Image Dodged	Color Balanced	Histogram Matched	Acq
1	✔		I16/wv_60cm_2016/37082/m_3708204_ne_17_1_2	Entire	NN	0.0000	✔						
2			16/wv_60cm_2016/37082/m_3708205_nw_17_1_2	Entire	NN	0.0000	✔						
3			I16/wv_60cm_2016/37082/m_3708205_ne_17_1_2	Entire	NN	0.0000	✔						
4			16/wv_60cm_2016/37082/m_3708205_sw_17_1_2	Entire	NN	0.0000	✔						
5			I16/wv_60cm_2016/37082/m_3708204_se_17_1_2	Entire	NN	0.0000	✔						
6			I16/wv_60cm_2016/37082/m_3708205_se_17_1_2	Entire	NN	0.0000	✔						

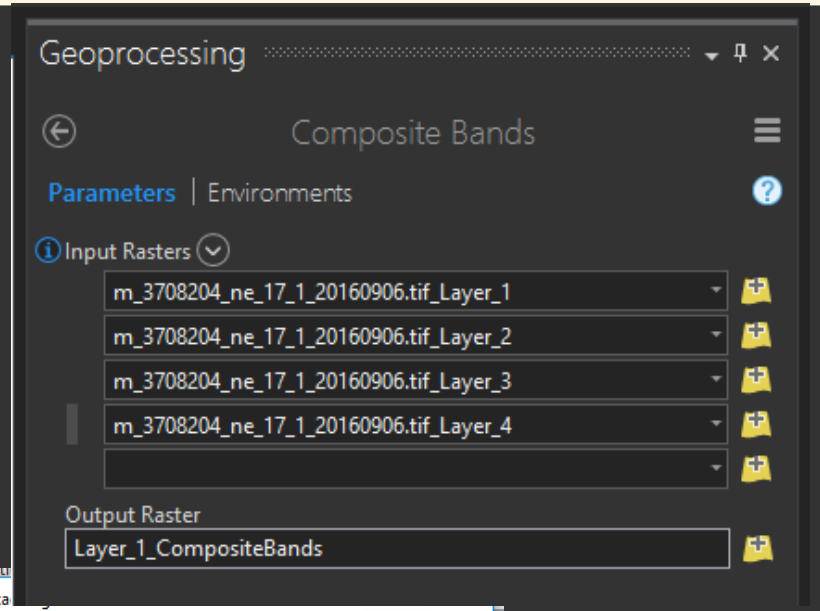
Video: Mosaic to New Raster

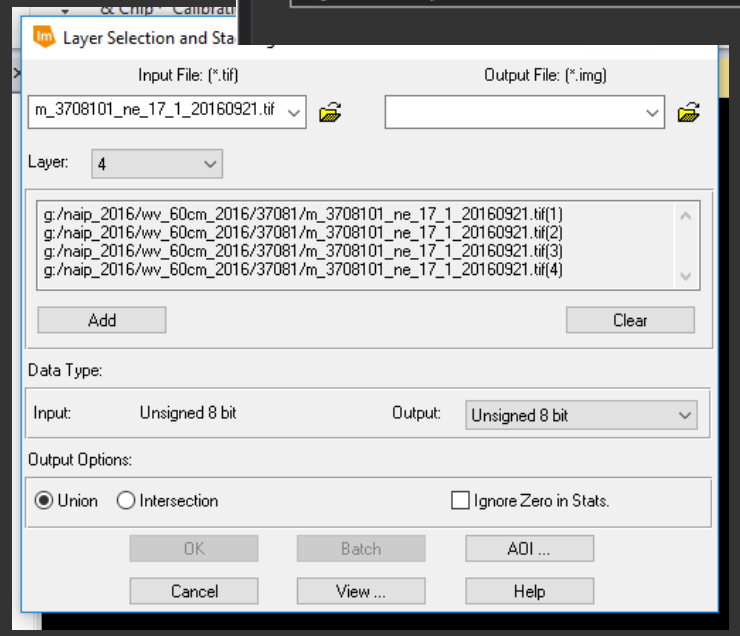


Stack Grids

- Stack or combine individual grids into a multiband raster
- Commonly used for image data
- Can be used for all raster data, not just images
- Output bands or layers will all have the same pixel type
- Bands will be layered in the order provided

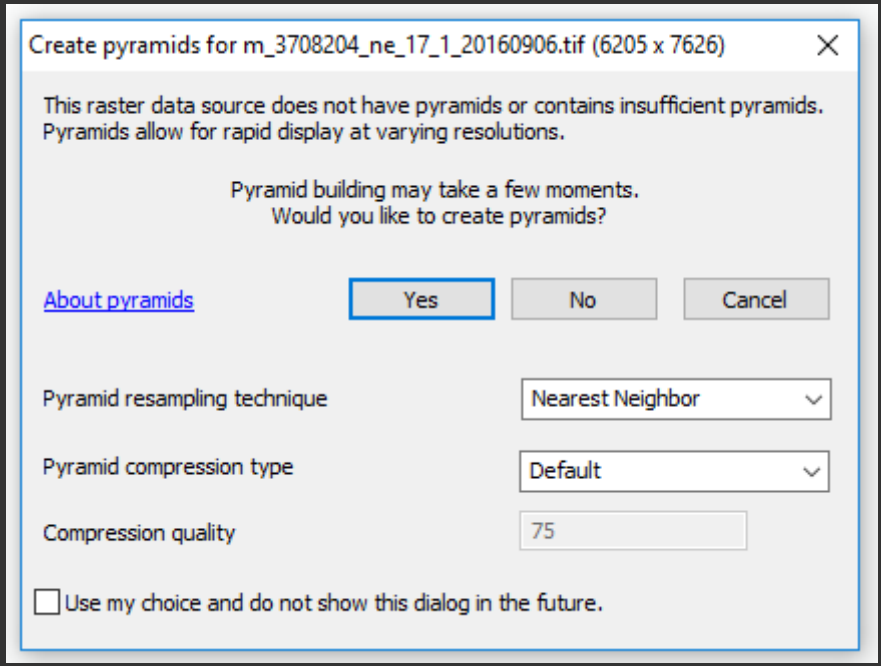






Pyramids

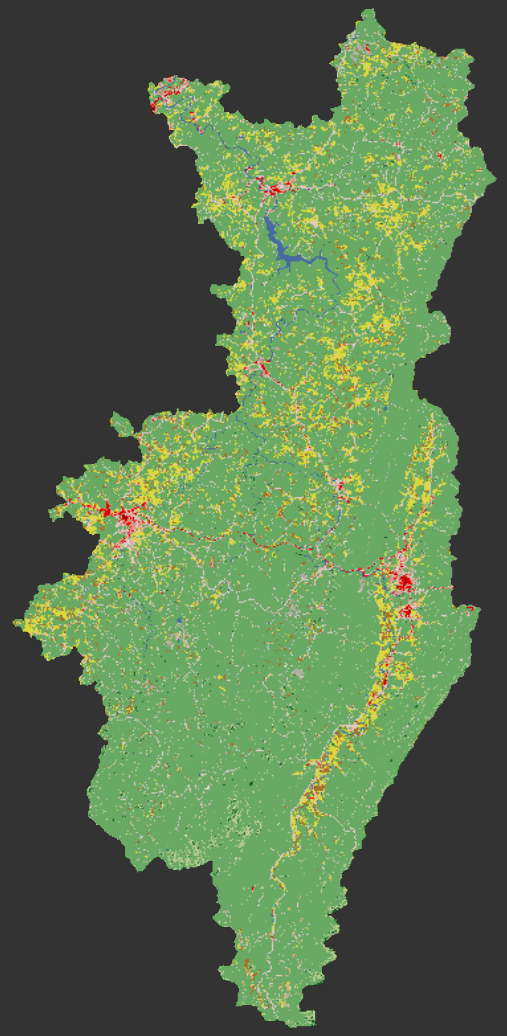
- Reduce spatial resolution versions of the data to aid in faster display

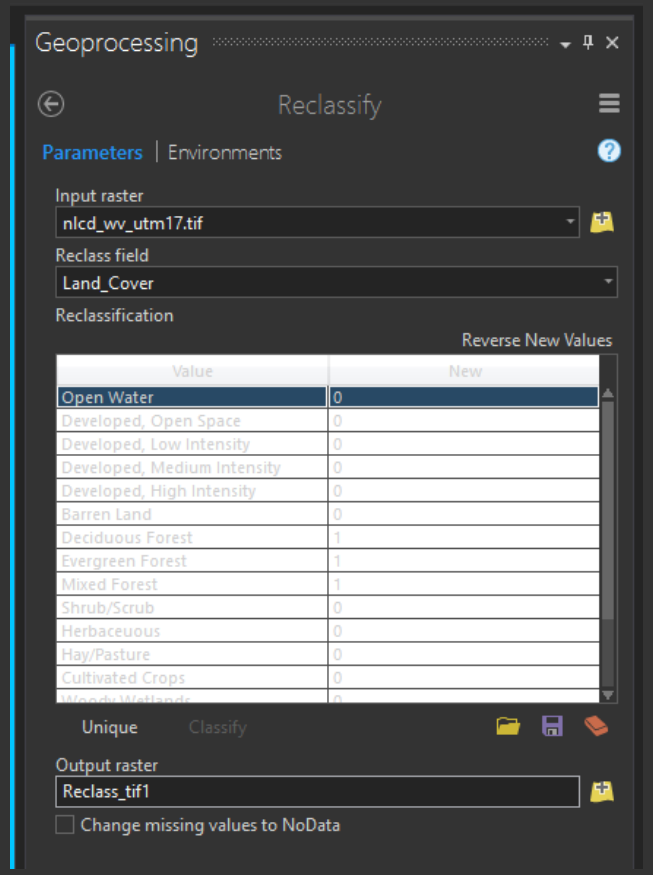


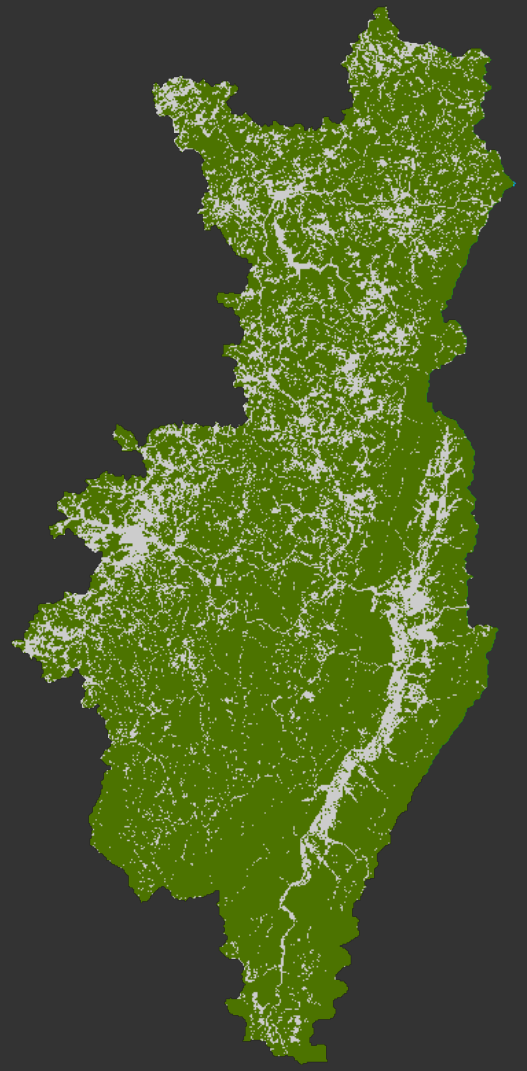
Reclassification

Reclassify Categorical Raster

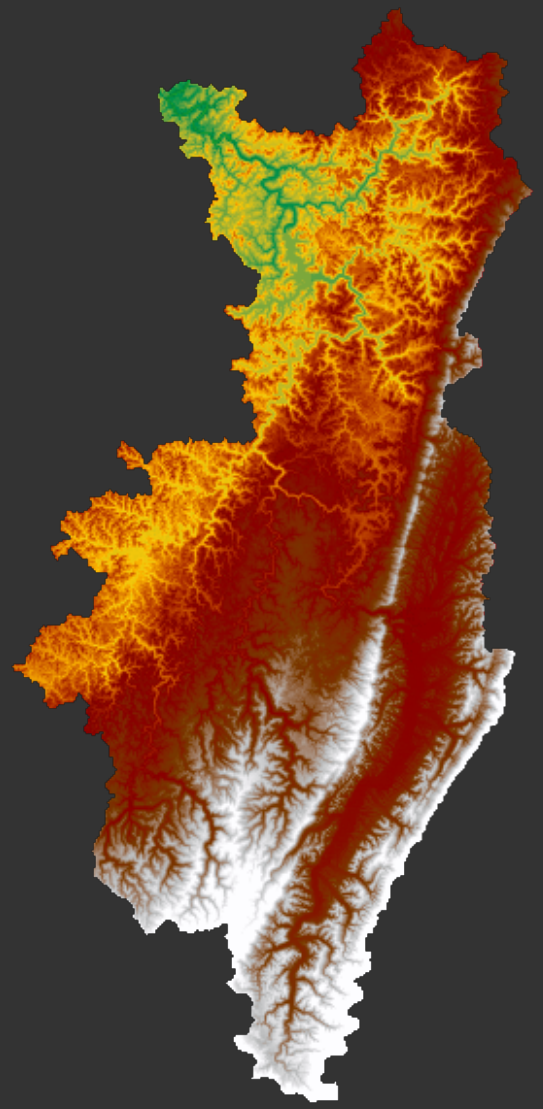
- Change cell values

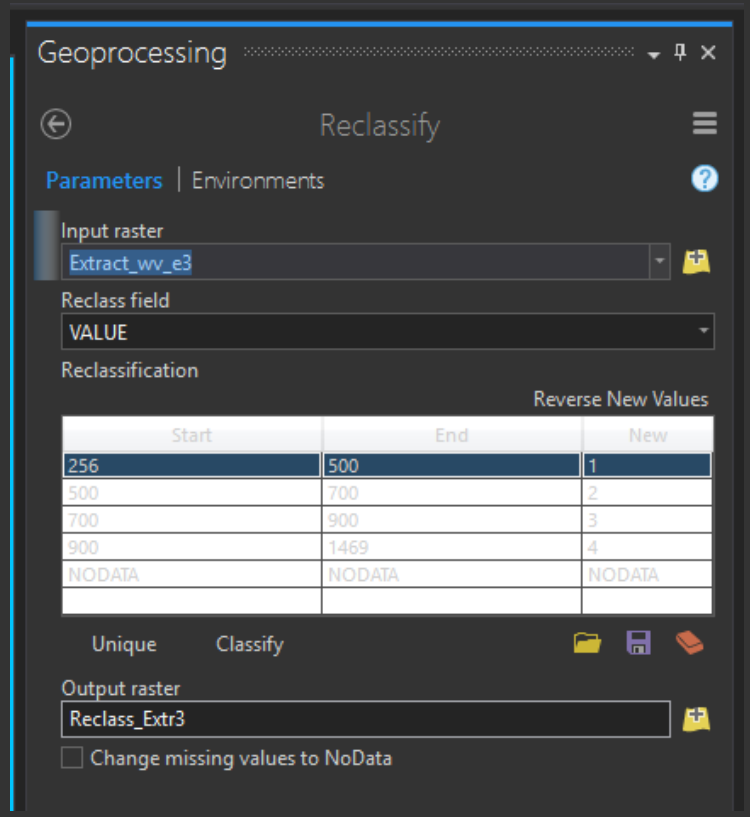


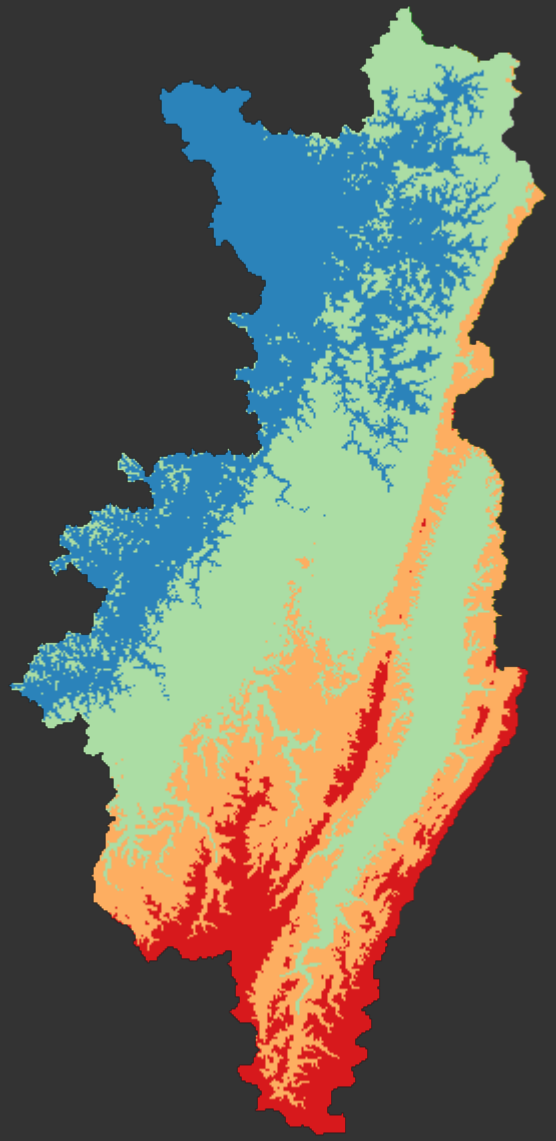




Reclassify Continuous Raster Data







Reclassify NoData

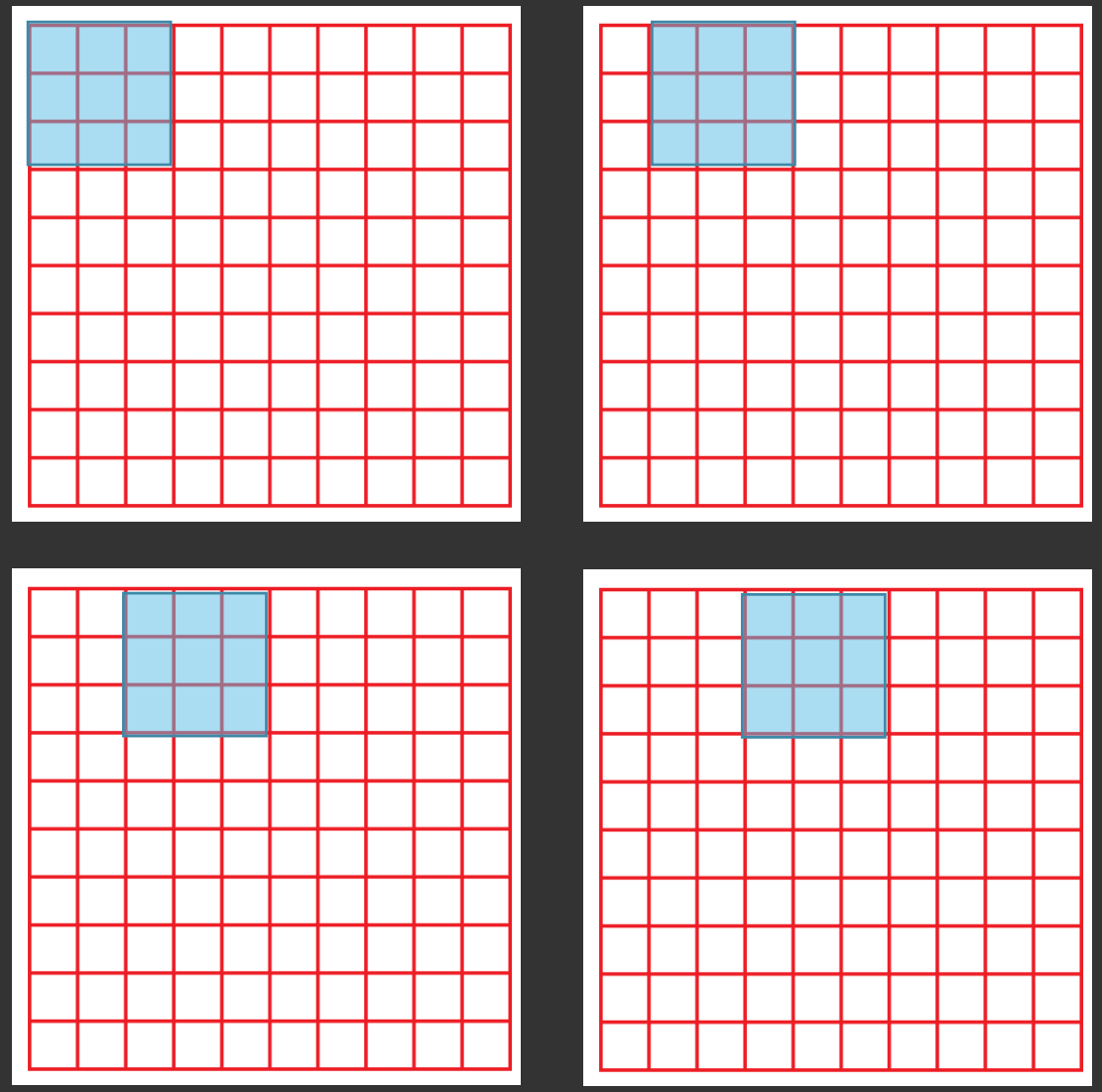
- Can reclassify NoData to a new value

Video: Raster Reclassify

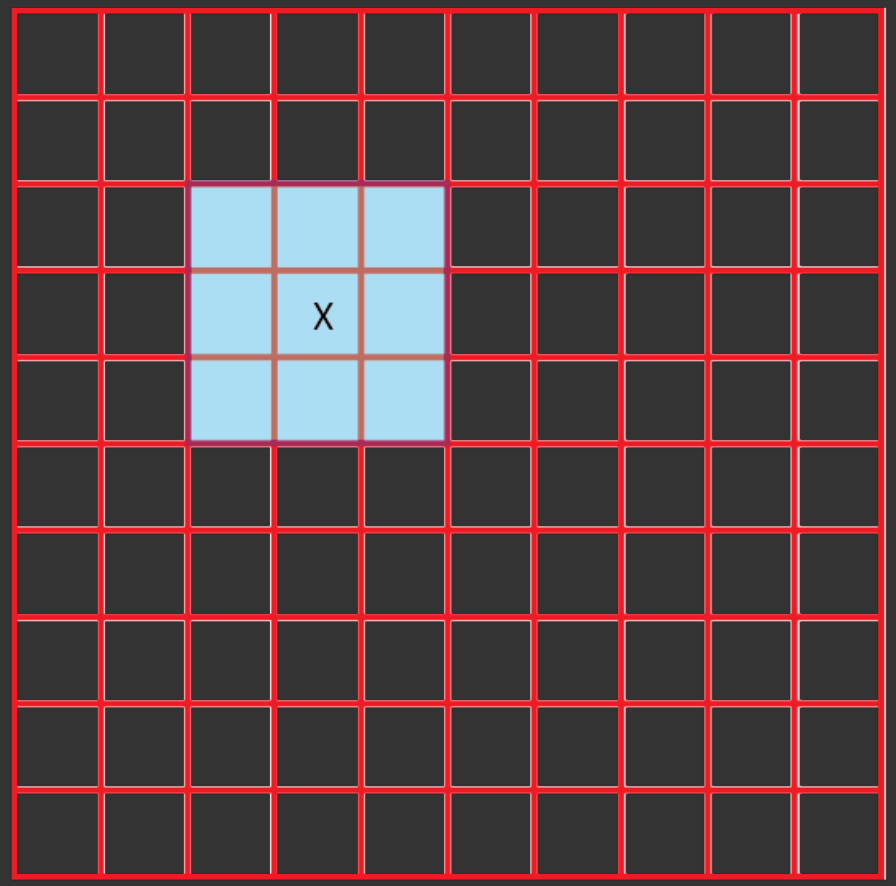
Neighborhood-Based Analysis

What is a neighborhood?

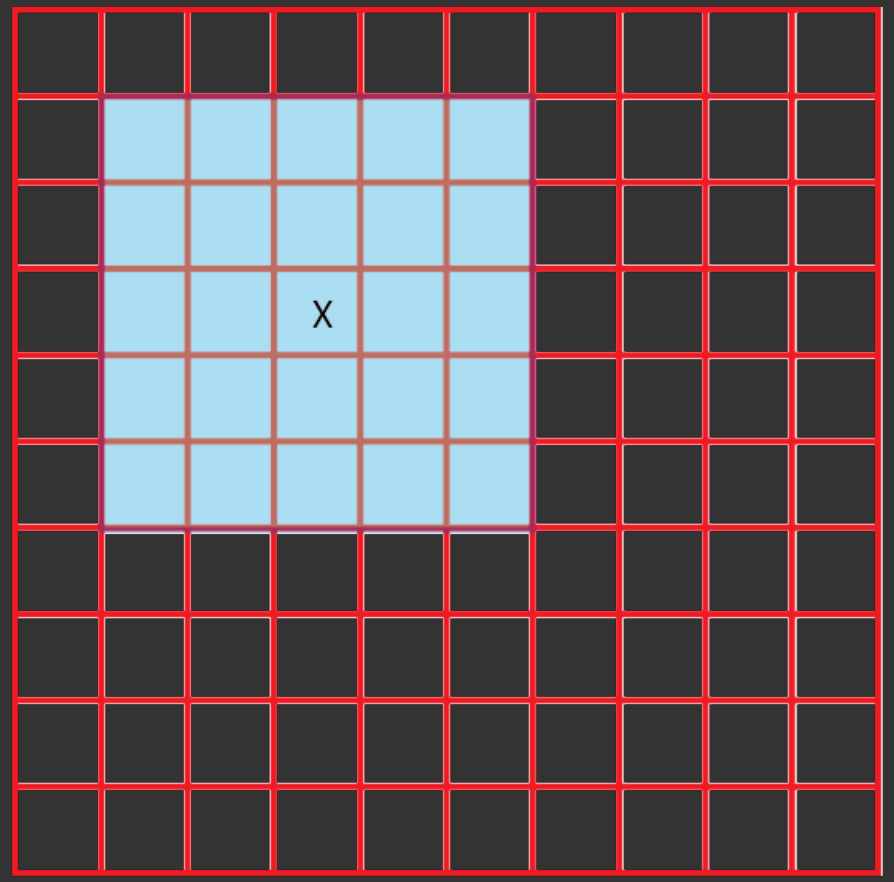
- Neighborhood analysis, moving window analysis, focal operation, kernel analysis
- Make calculation or compare cell values around a center cell



Defining a Neighborhood

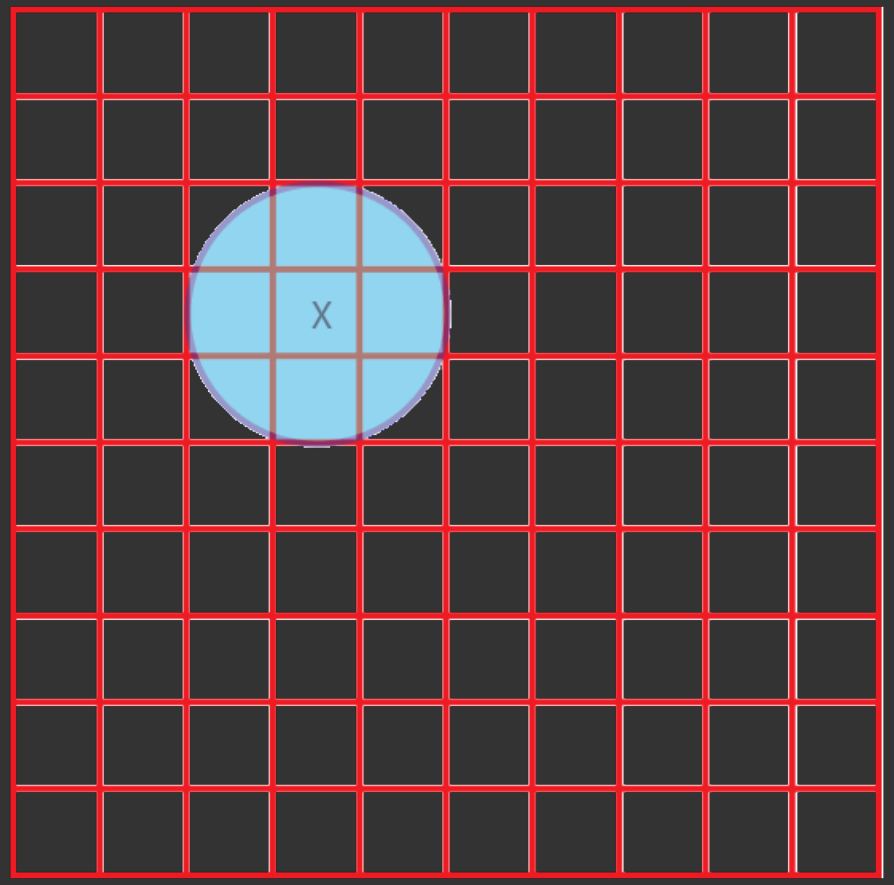


Rectangle, Width = 3 cells
Height = 3 cells

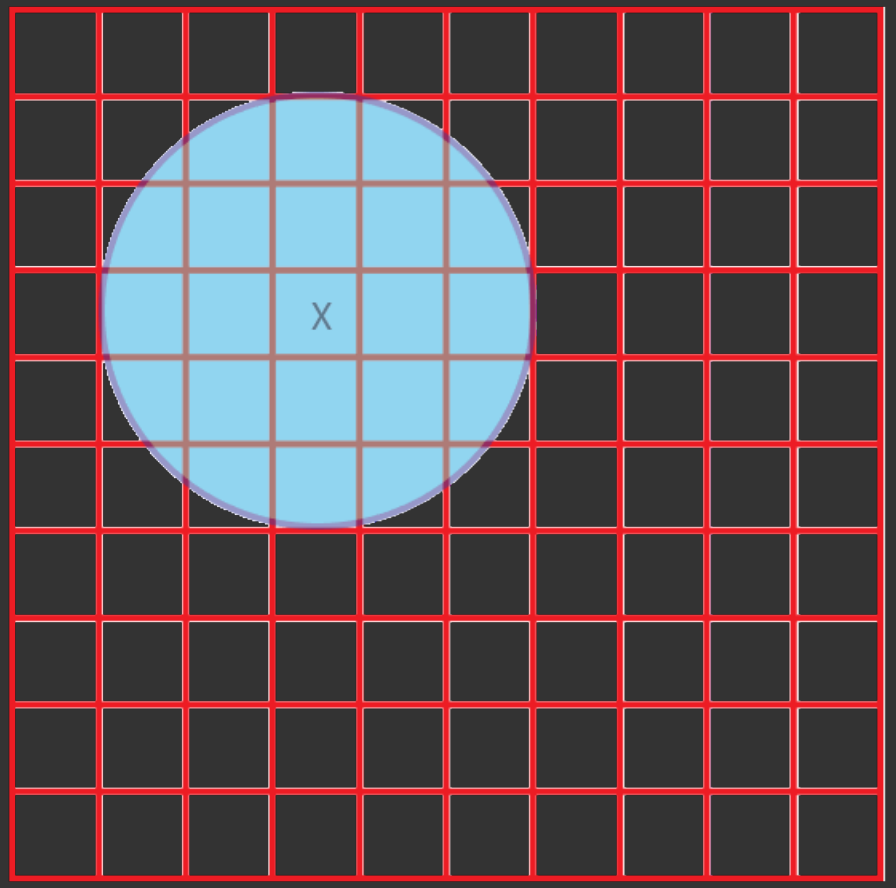


Rectangle, Width = 5 cells
Height = 5 cells

Defining a Neighborhood

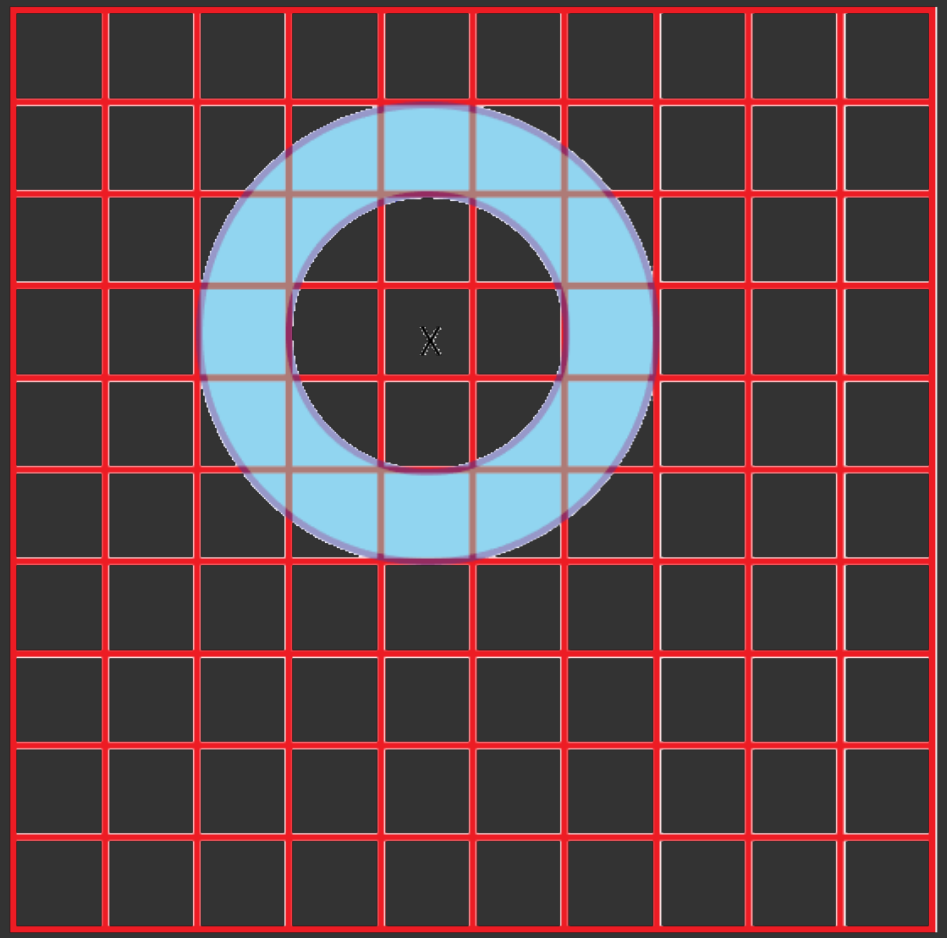


Circle, Radius = 1 cell



Circle, Radius = 2 cells

Defining a Neighborhood

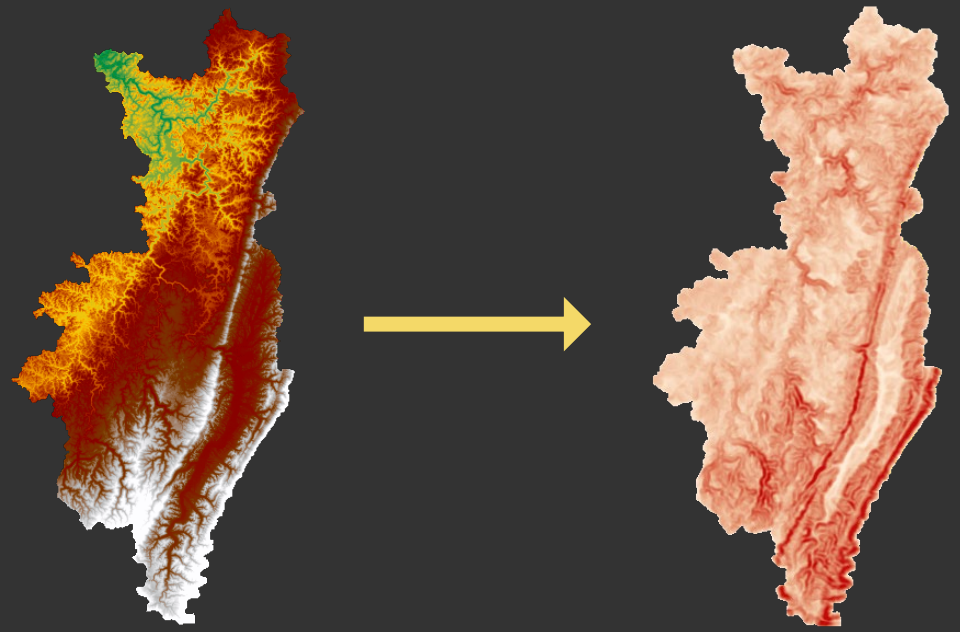


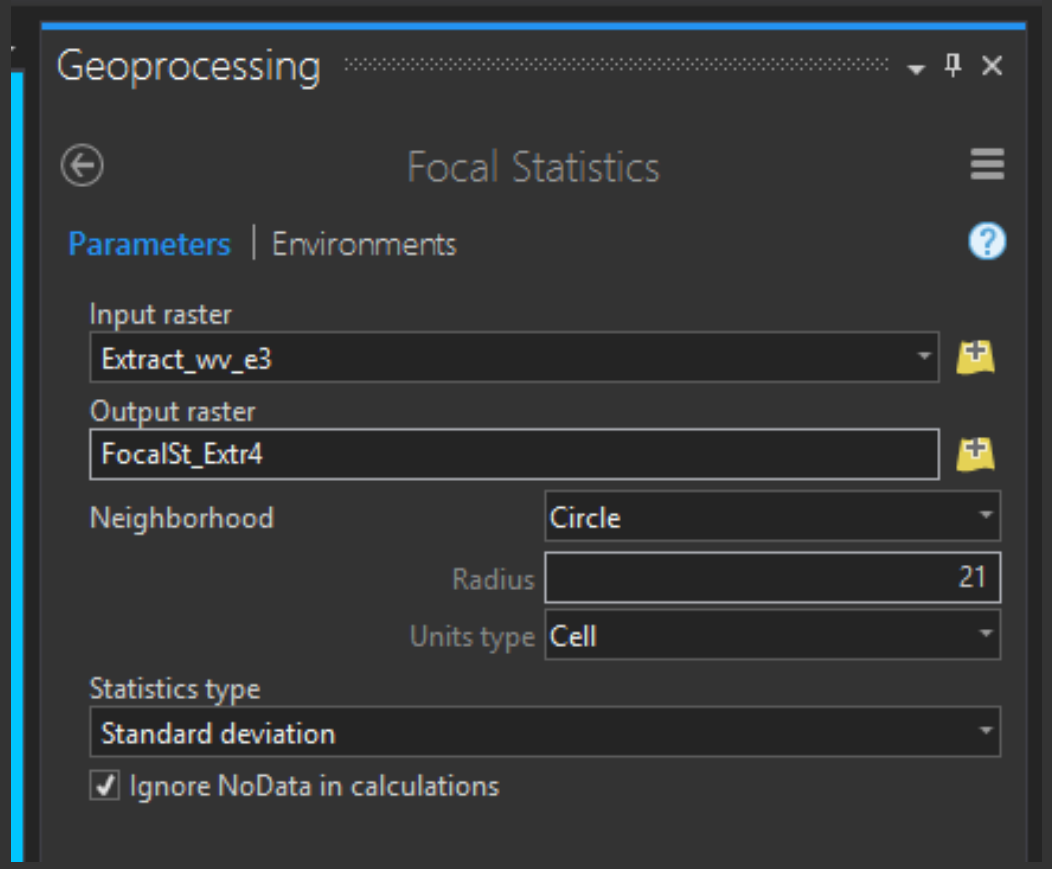
- Wedge = Wedge shape radiating from center cell that is specified using a start angle, end angle, and radius
- Irregular = Irregular shape specified by a window or kernel

Annulus, Inner Radius = 1 cell, Out Radius = 1 cell

Focal Statistics

- Calculates a statistic within the window
- Stores result on center cell in new output
- Completes operations for all cells

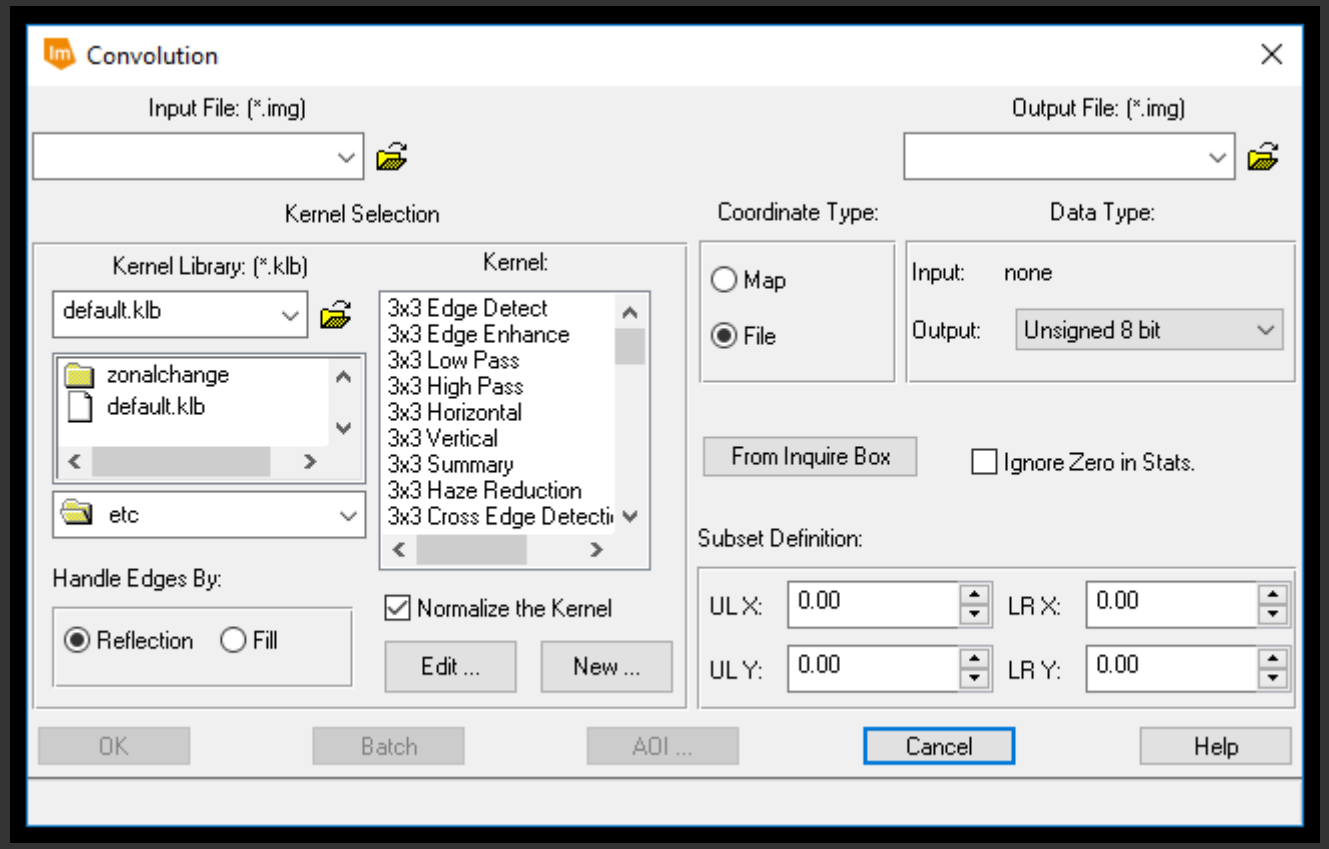


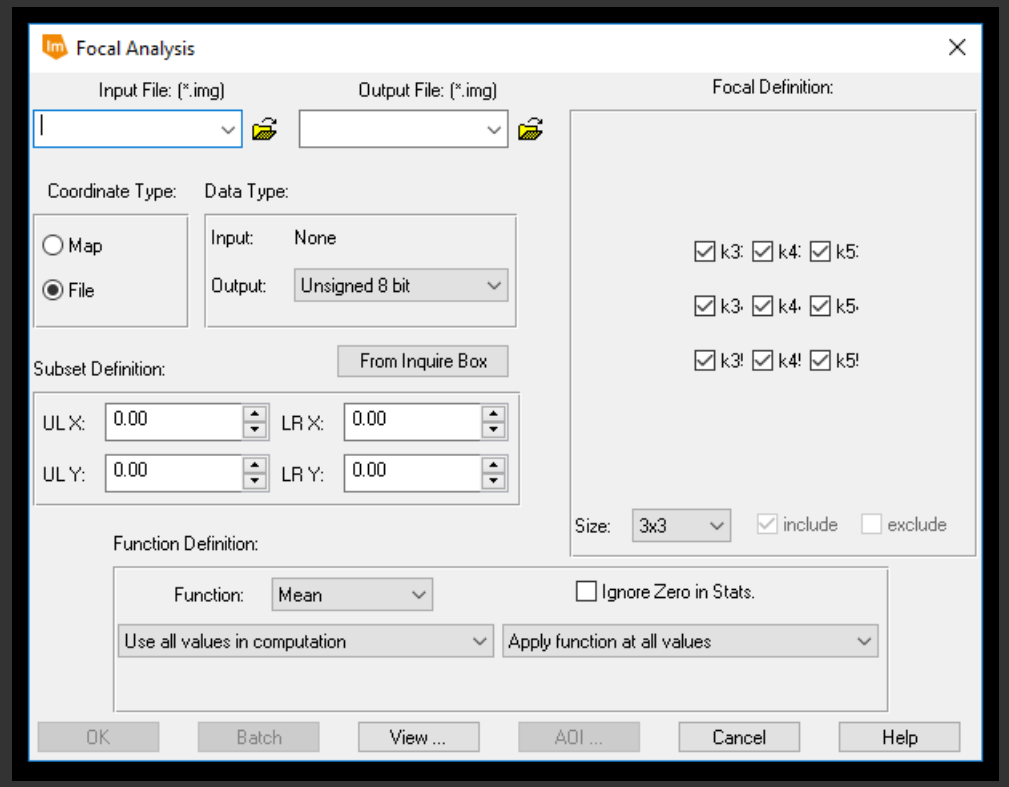


Focal Statistics

- MEAN = Calculates the mean (average value) of the cells in the neighborhood.
- MAJORITY = Calculates the majority (value that occurs most often) of the cells in the neighborhood.
- MAXIMUM = Calculates the maximum (largest value) of the cells in the neighborhood.
- MEDIAN = Calculates the median of the cells in the neighborhood.
- MINIMUM = Calculates the minimum (smallest value) of the cells in the neighborhood.
- MINORITY = Calculates the minority (value that occurs least often) of the cells in the neighborhood.
- RANGE = Calculates the range (difference between largest and smallest value) of the cells in the neighborhood.
- STD = Calculates the standard deviation of the cells in the neighborhood.
- SUM = Calculates the sum (total of all values) of the cells in the neighborhood.
- VARIETY = Calculates the variety (the number of unique values) of the cells in the neighborhood.

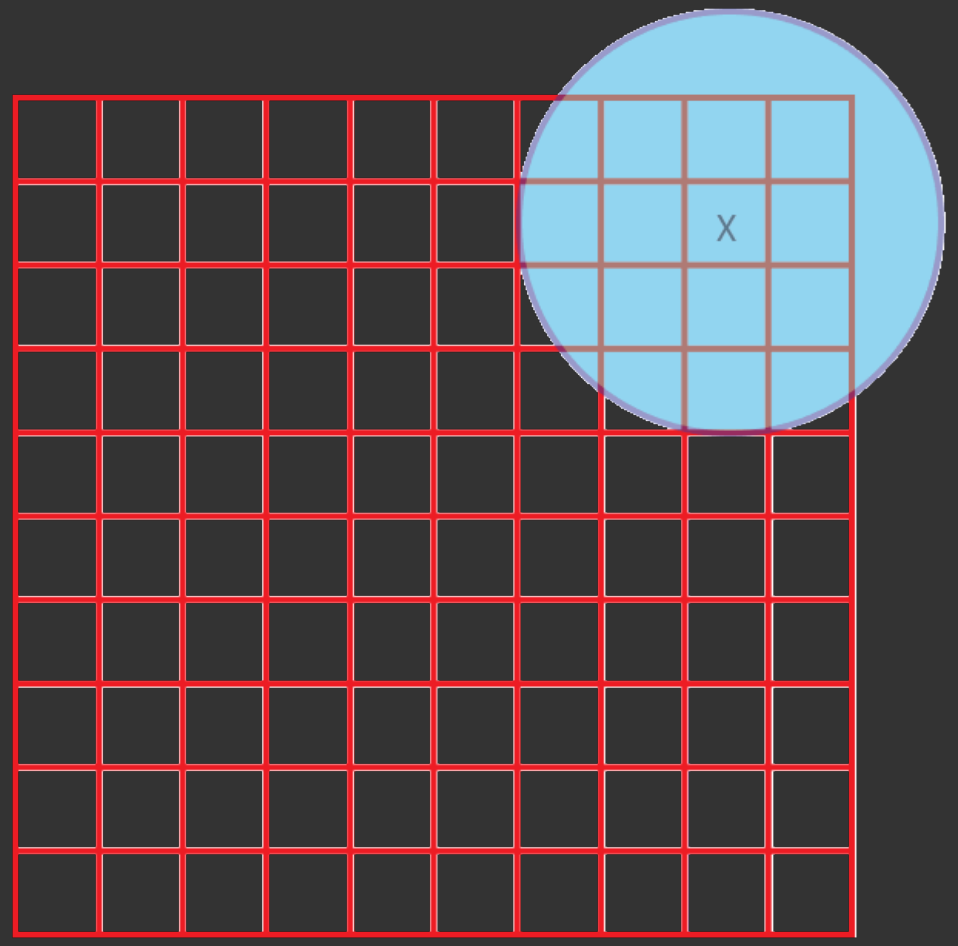
Focal Statistics in Remote Sensing





Edge Cells

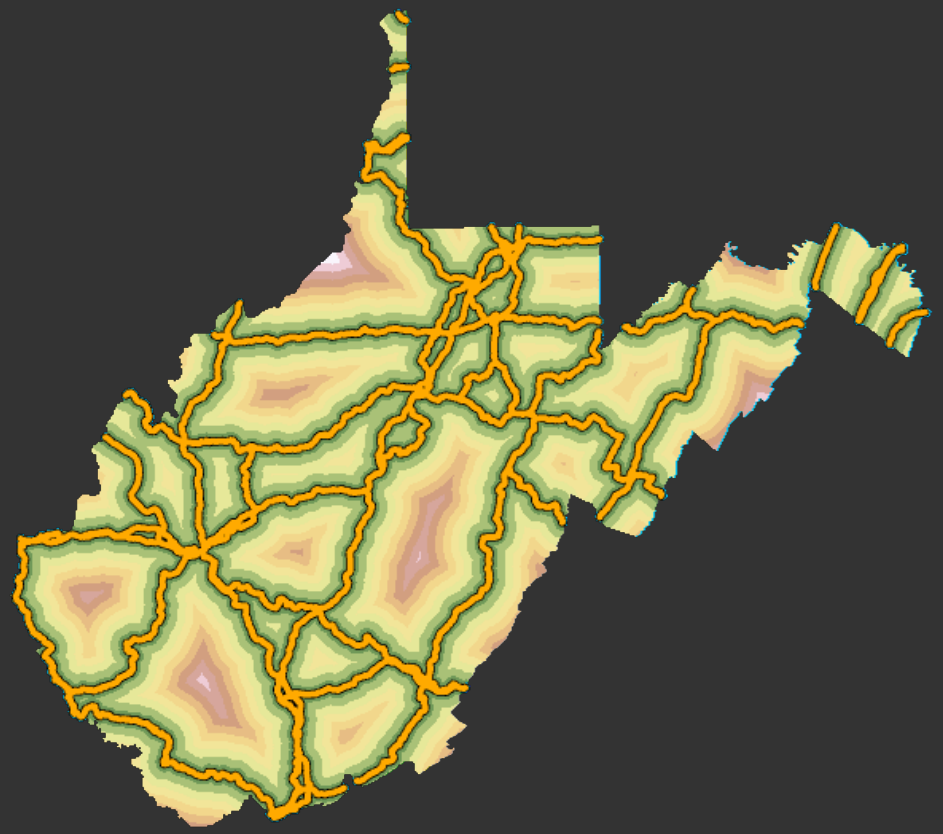
- Edge cells will not have a full set of neighbors

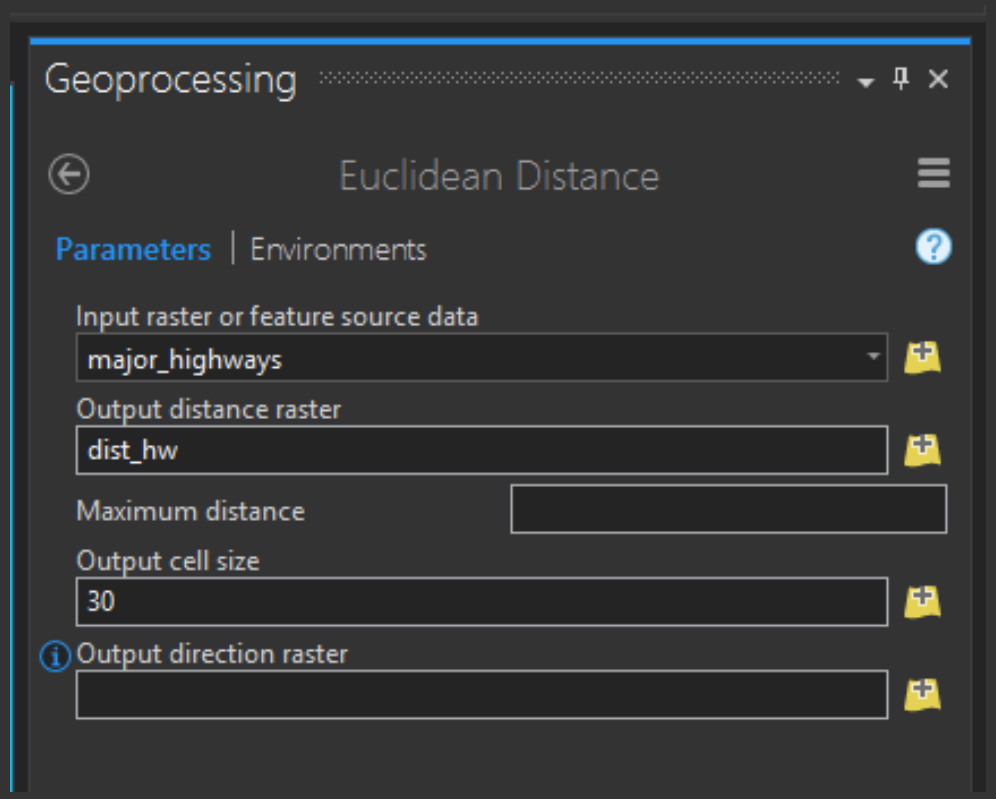


Distance

Euclidean Distance

- Straight line or Euclidean distance from a source to the cell





Video: Euclidean Distance

Is Euclidean distance meaningful?

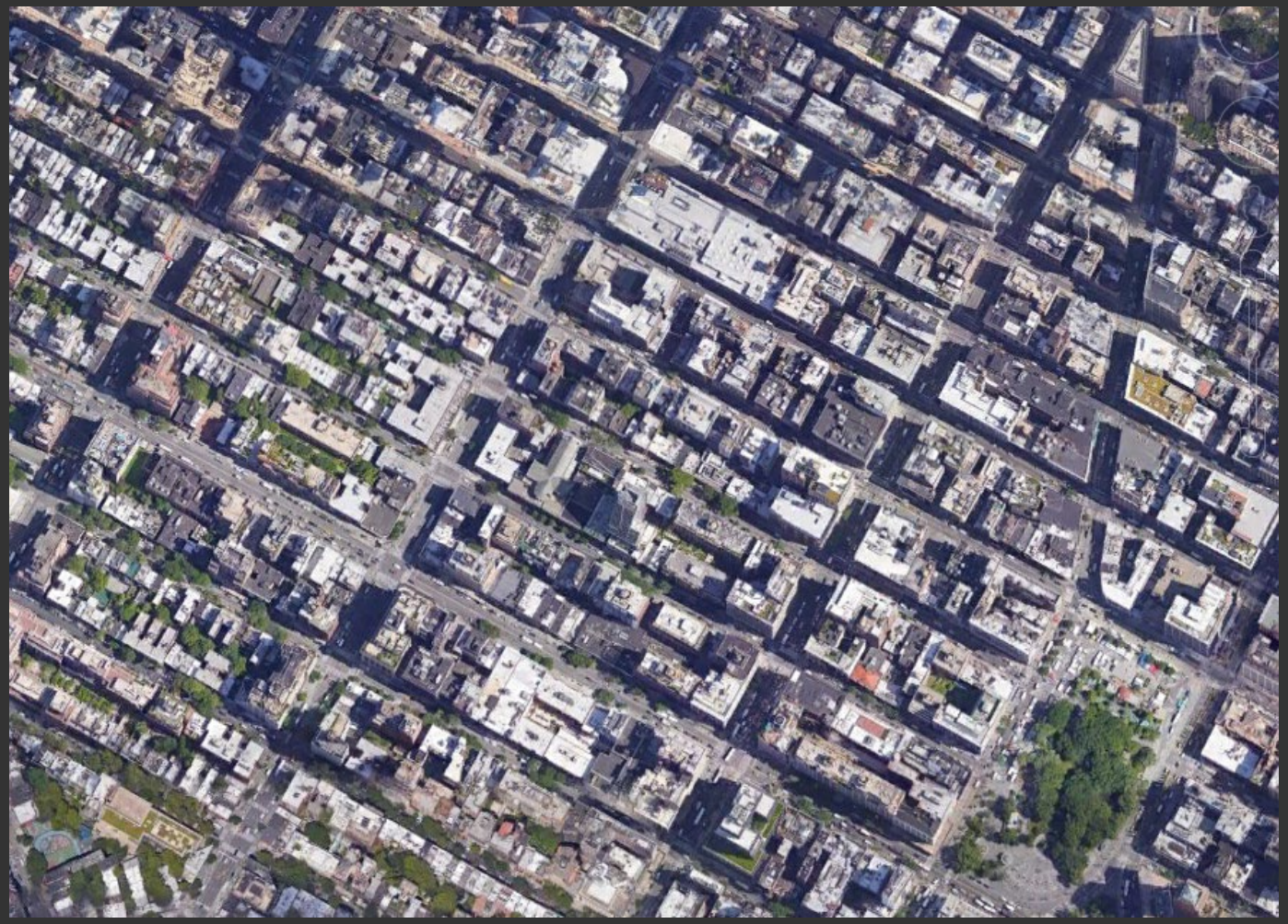
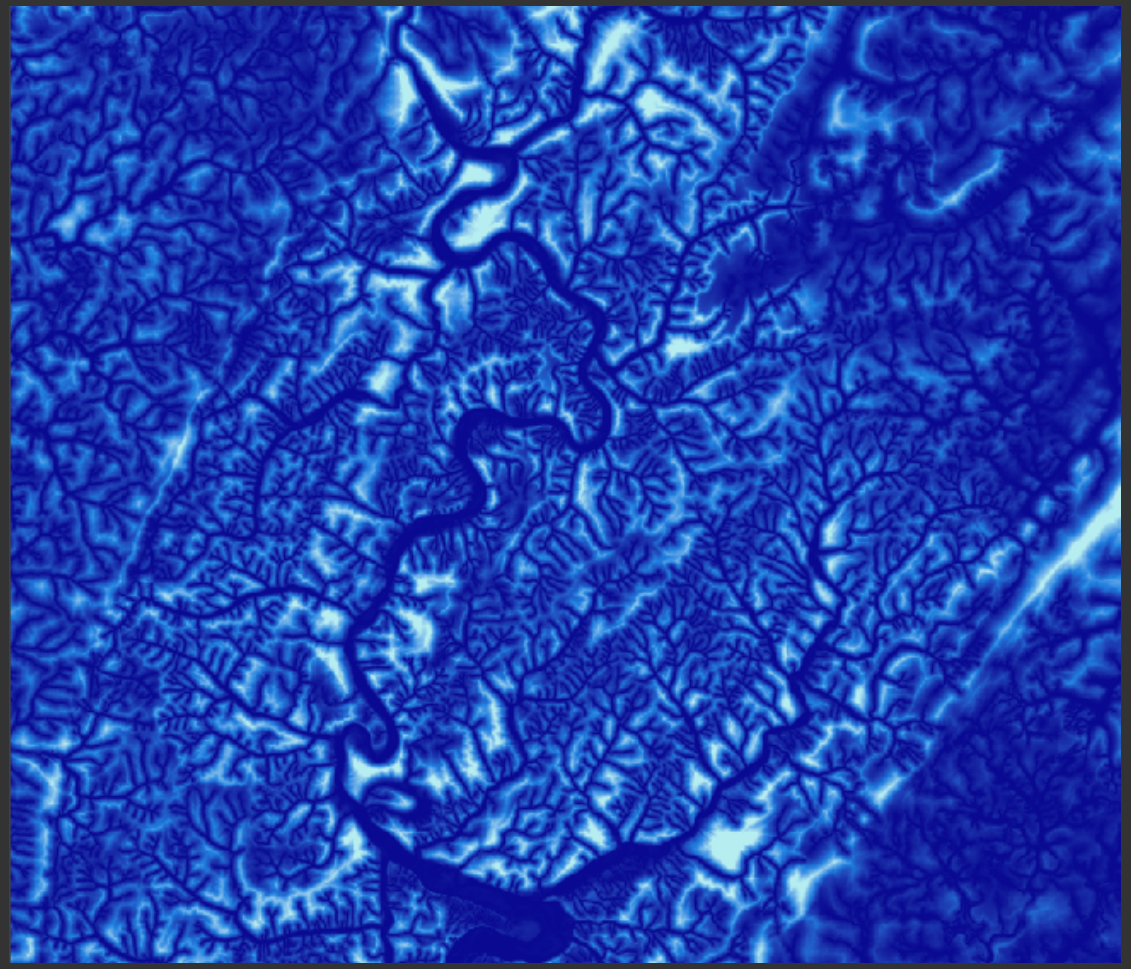


Image from Google Earth

Cost Distance

- Euclidean distance but with a cost or impedance applied



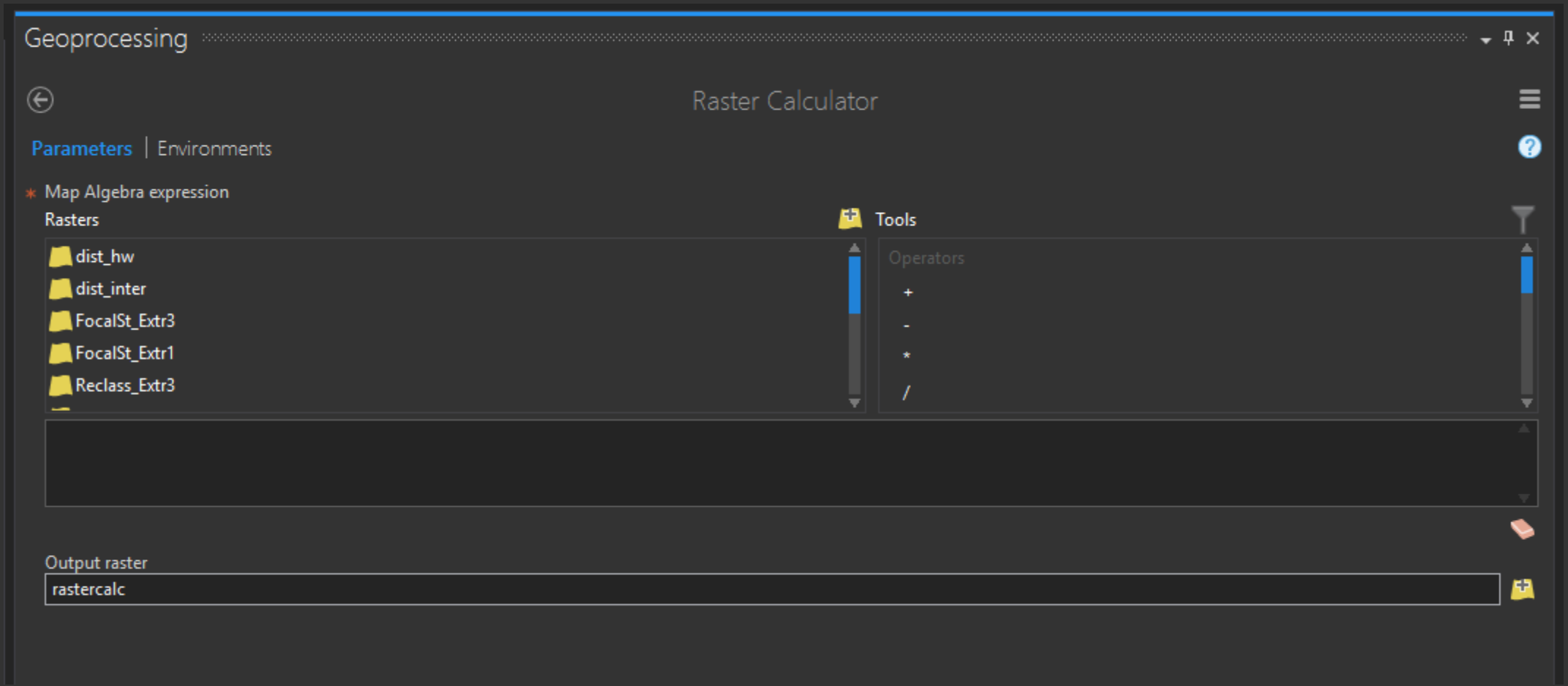
Example: Distance from streams weighted by slope

Distance Tools in ArcGIS Pro

- Distance
  - Legacy
  - Corridor
  - Distance Accumulation
  - Distance Allocation
  - Optimal Path As Line
  - Optimal Path As Raster
  - Optimal Region Connections

Raster Math

Raster Calculator

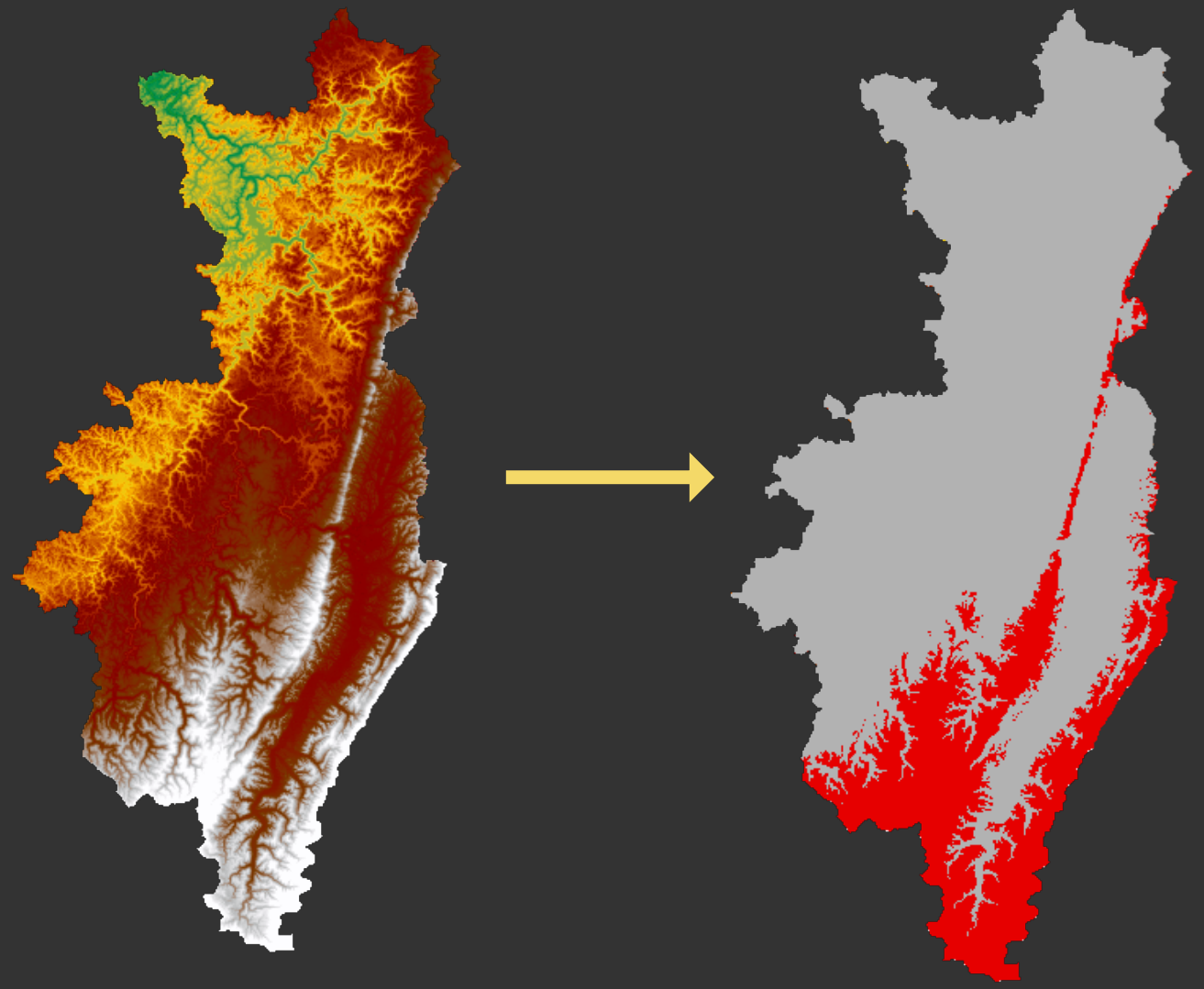


Produce Binary Raster Grid

- "Elevation" > 800
- 1 = Yes = True
- 0 = No = False

850	700	820
600	820	900
NoData	650	675

1	0	1
0	1	1
NoData	0	0

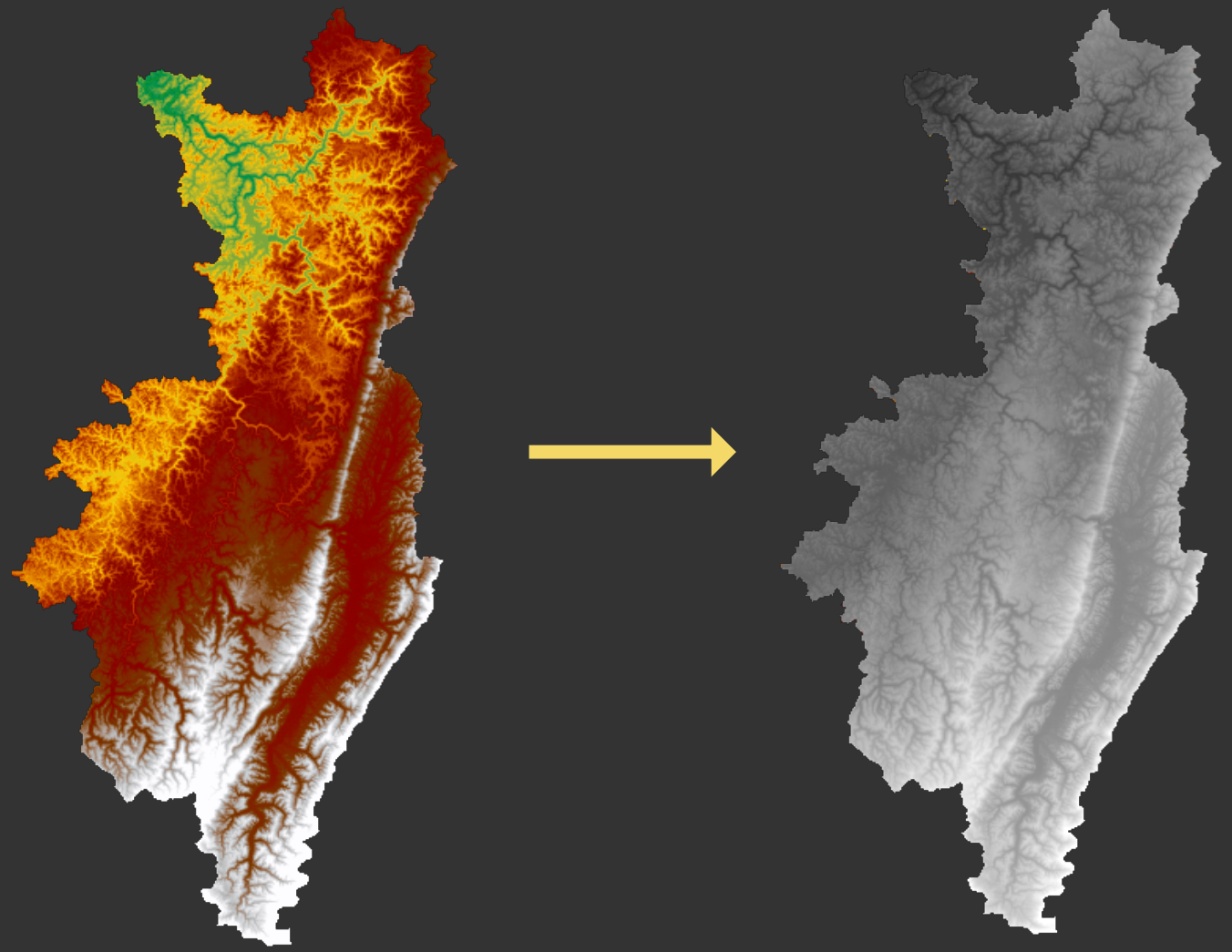


Operations Involving A Single Raster

- SquareRoot("Elevation")

850	700	820
600	820	900
NoData	650	675

29.2	26.5	28.6
24.5	28.6	30
NoData	25.5	26.0

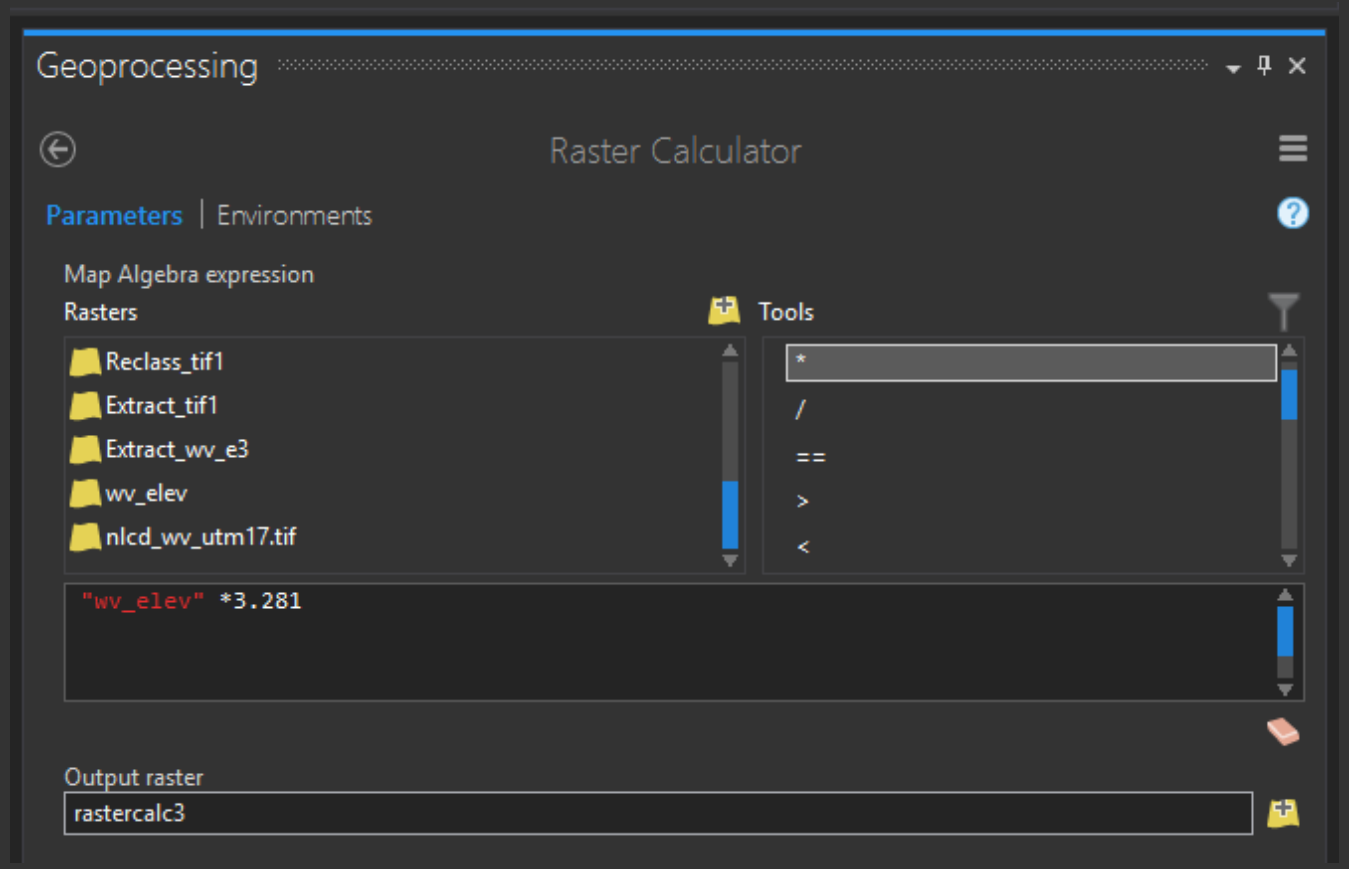


Operations Involving Raster Grids and Constants

- "Elevation" * 3.281

850	700	820
600	820	900
NoData	650	675

2789	2297	2690
1969	2690	2953
NoData	2133	2215



Operations Involving Multiple Raster Grids

1	0	1
0	0	1
NoData	1	1

X

1	NoData	1
0	1	0
NoData	1	NoData

=

1	NoData	1
0	0	0
NoData	1	NoData

1	0	1
0	0	1
NoData	1	1

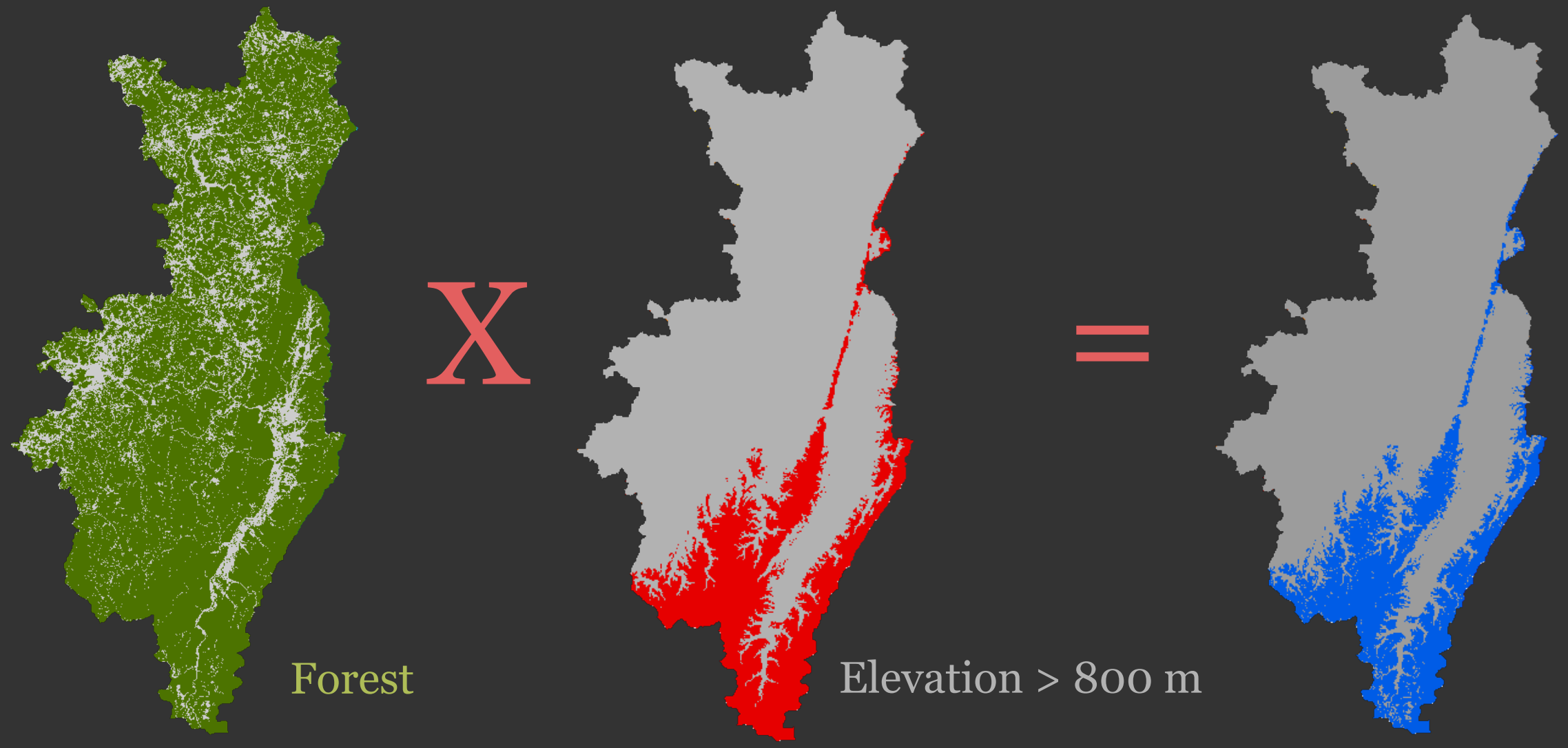
+

1	NoData	1
0	1	0
NoData	1	NoData

=

2	NoData	2
0	1	1
NoData	2	NoData

Operations Involving Multiple Raster Grids



Some Useful Functions

+ Add
- Subtract
* Multiply
/ Divide
== Equal to
!= Not equal to
> Greater than
>= Greater than or equal to
< Less than
<= Less than or equal to
& Boolean AND
| Boolean OR
^ Boolean XOR
~ Boolean NOT

Some Useful Functions

Abs Absolute value

Exp Base e exponential

Exp10 Base 10 exponential

Exp2 Base 2 exponential

Float Convert from integer to float

Int Convert from float to integer

Ln Natural log

Log10 Base 10 log

Log Base 2 log

Square Calculates square

SquareRoot Calculates square root

IsNull Identifies NoData cells

Conditional Statements

- Con(set condition, what to return if true, what to return if false)

Example: Con("Land_Cover" = 41, 1, 0)

- If the land cover raster grid is assigned a value of 41 (deciduous forest), return 1. If the land cover grid is assigned any other value, return 0.

Impact of NoData on Raster Math

- NoData cells return NoData!!!!!!
- Operations are only completed where all cell values are available

1	0	1
0	0	1
NoData	1	1

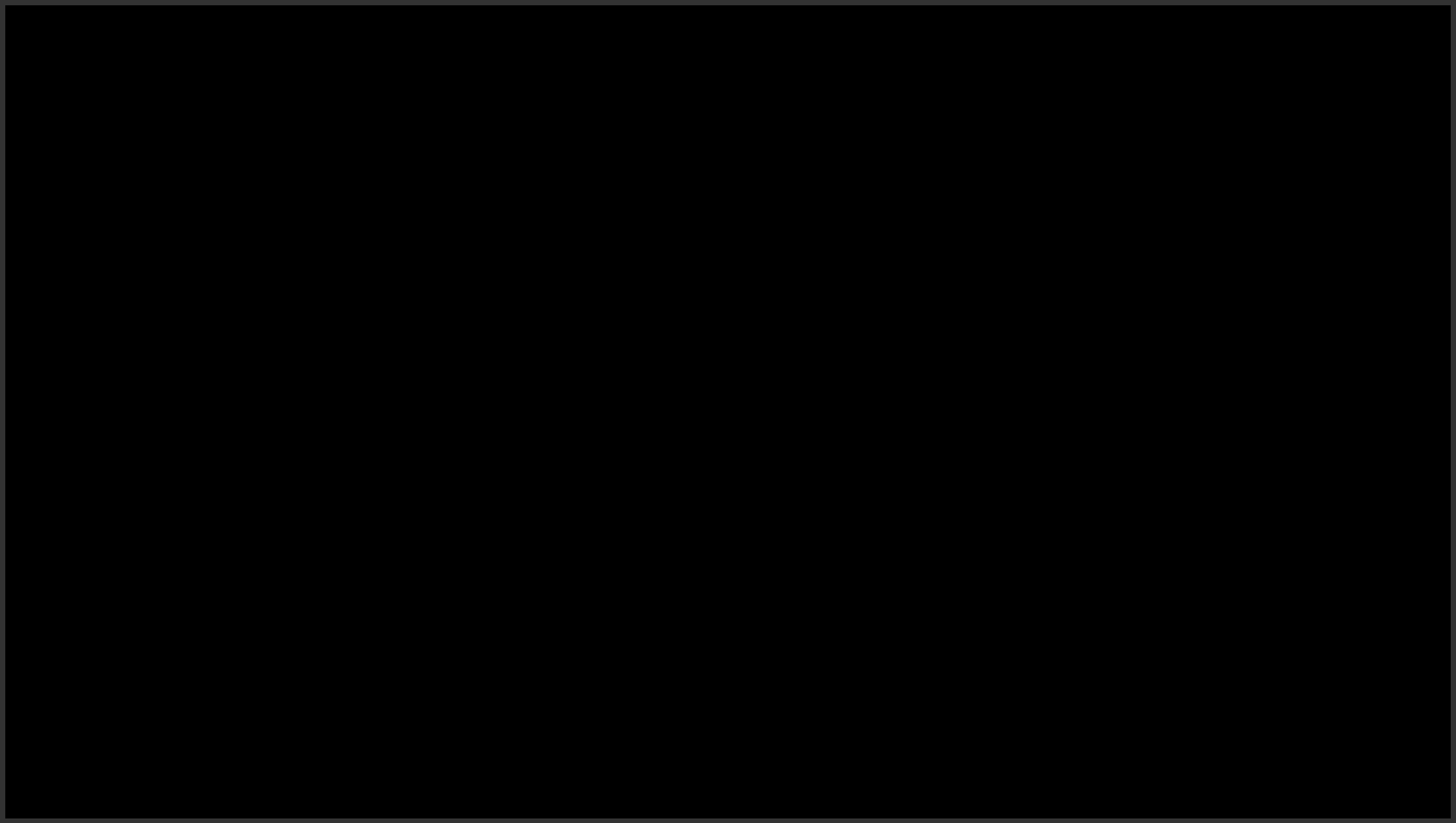
X

1	NoData	1
0	1	0
NoData	1	NoData

=

1	NoData	1
0	0	0
NoData	1	NoData

Video: Raster Calculator



Raster Generalization

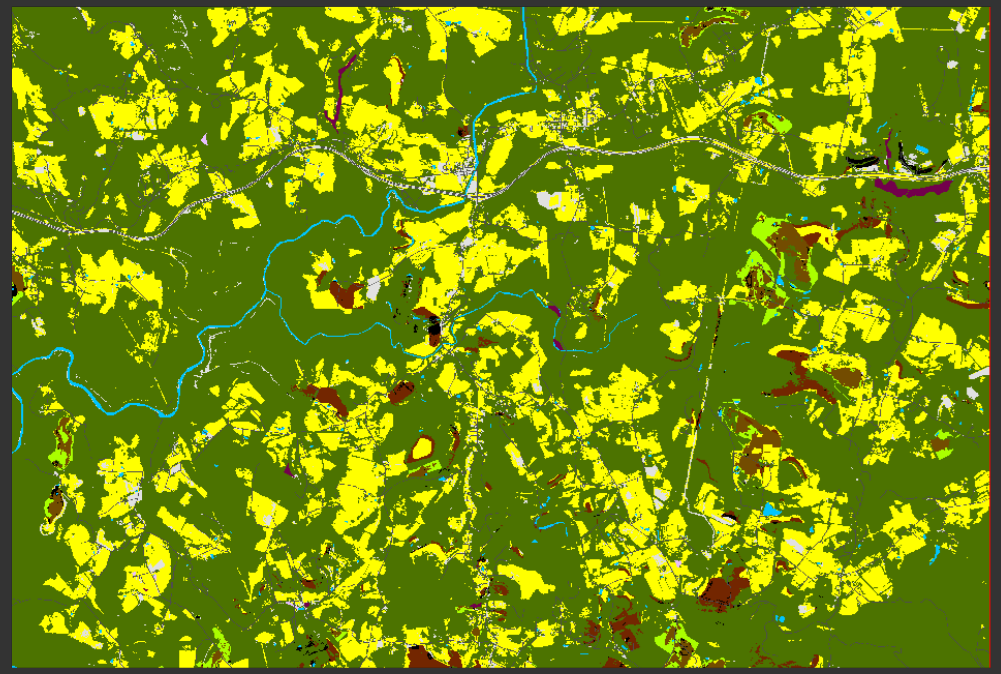
Majority Filter

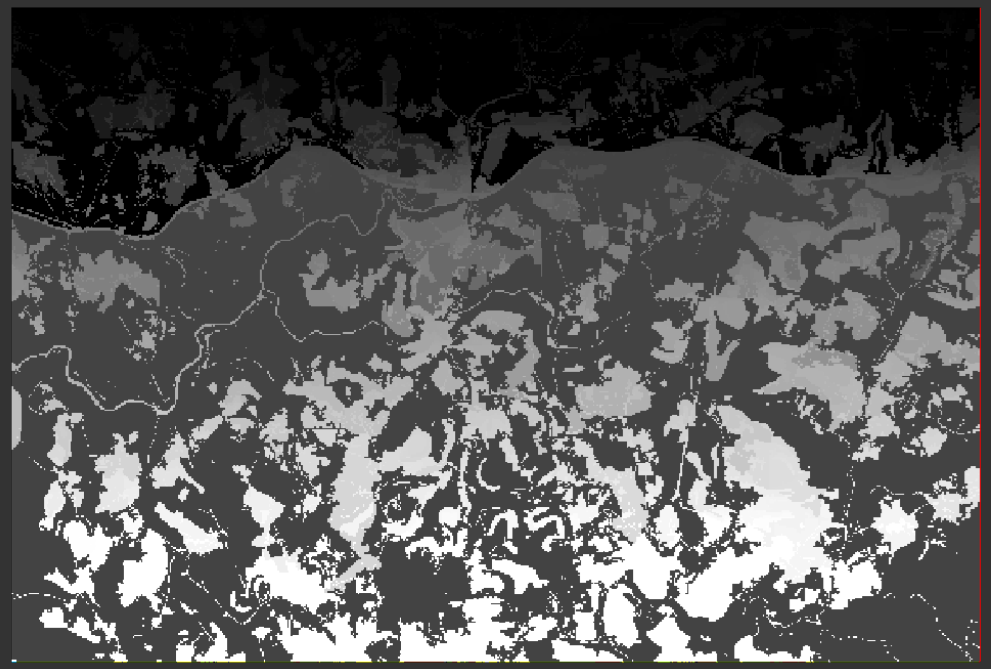
- Replace center cell with majority value in 3 x 3 cell window
- FOUR vs. EIGHT = use just orthogonal cells or orthogonal and diagonal cells
- MAJORITY vs. HALF = Must have a majority or only half to change value
- This is used to generalize categorical raster data

30	20	30
30	20	20
40	30	30

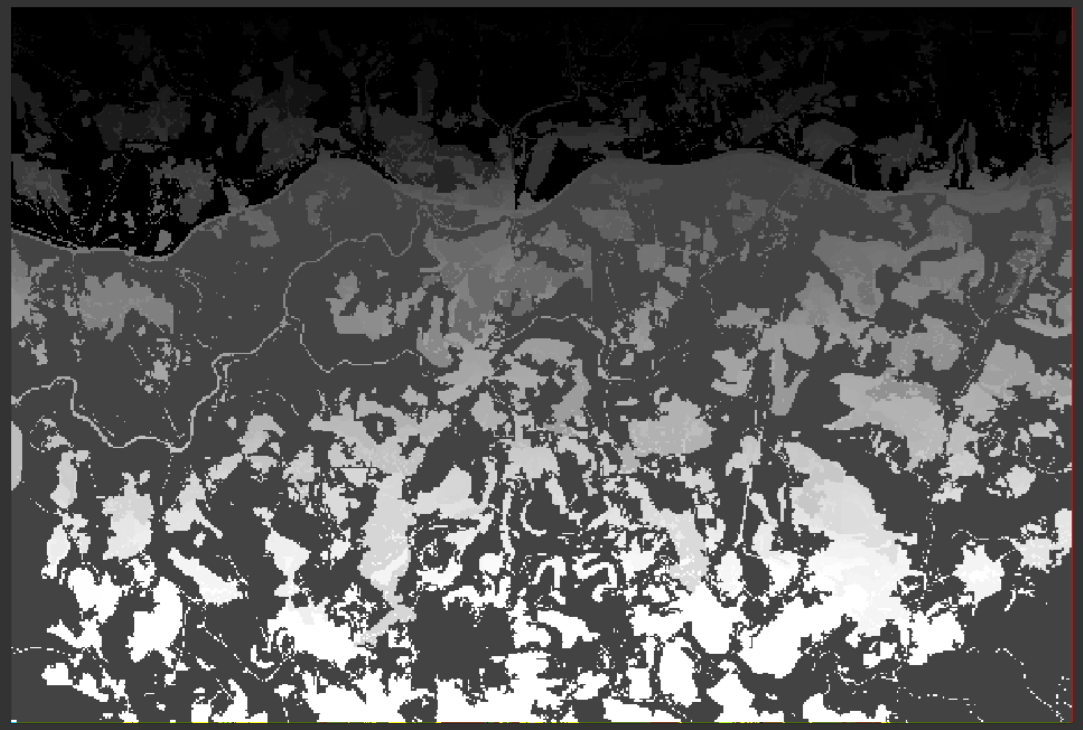
Region Group

- Group cells with the same code in a categorical raster and code them with a unique identifier



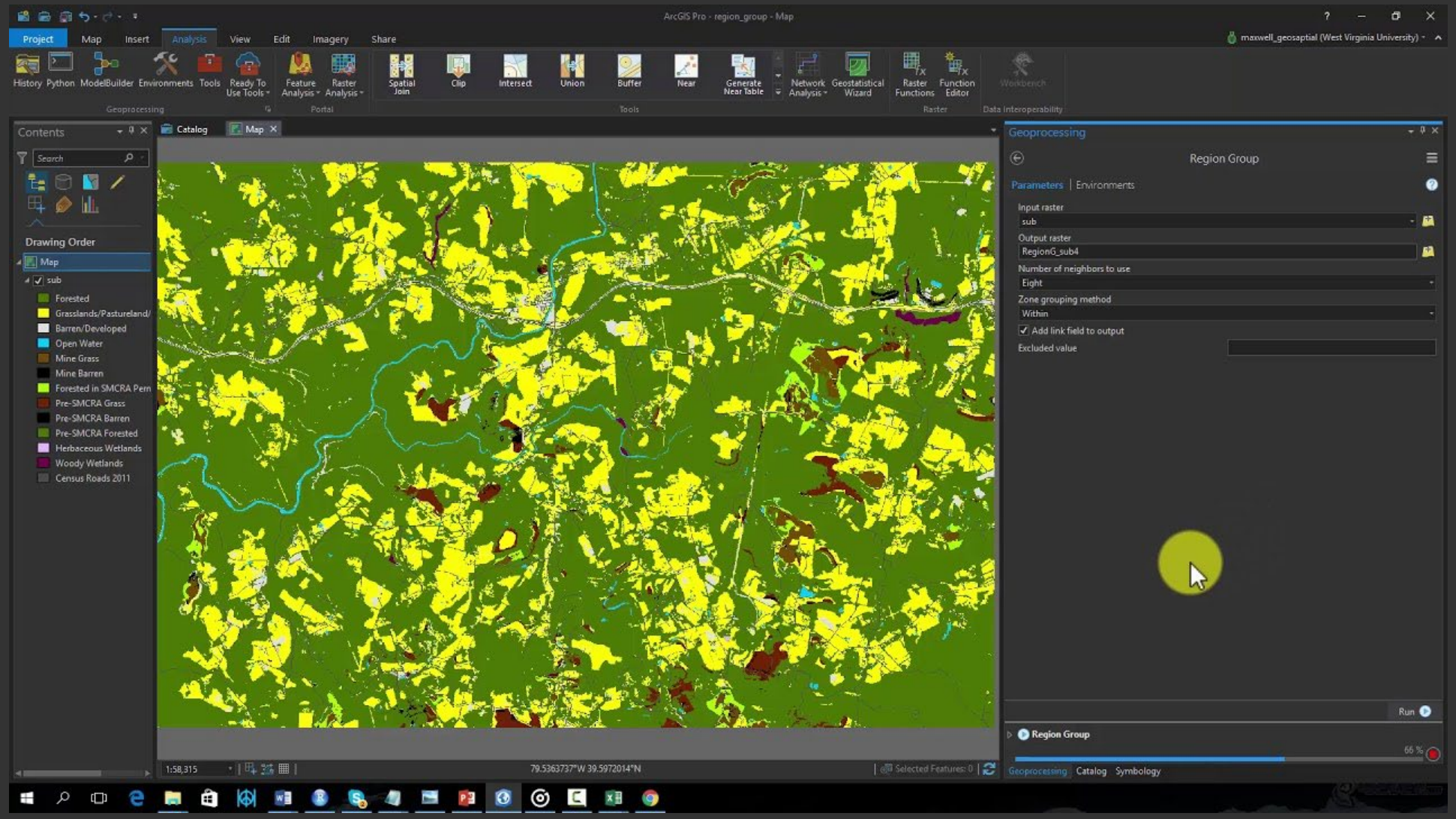


Region Group



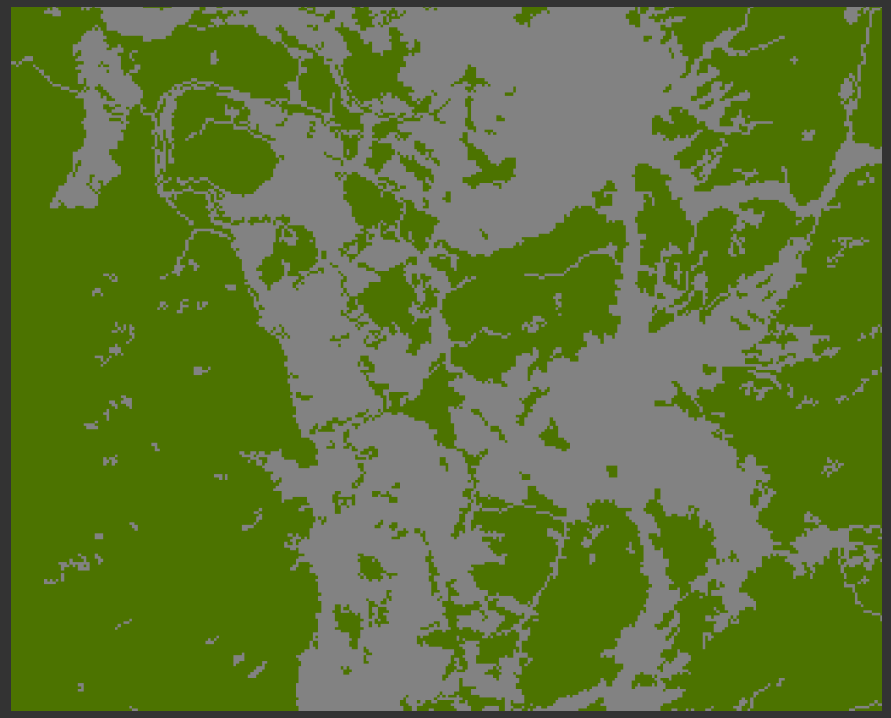
- Must decide between the FOUR or EIGHT method
- Can convert to polygons after regions are grouped
- Will needed to decide if you want to simply the polygons

Video: Majority Filter



Expand

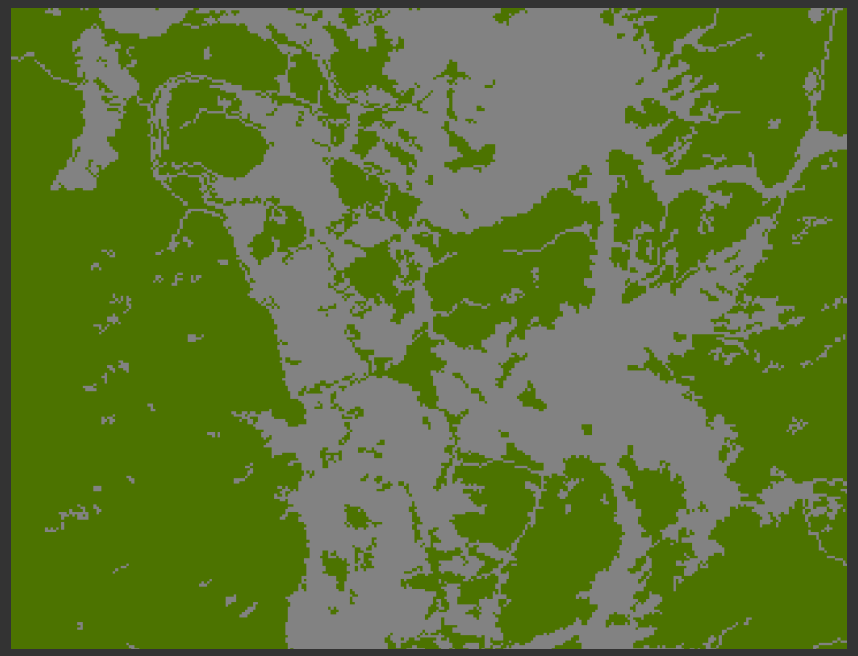
- Expand out a specific category in a categorical raster by a specified number of cells

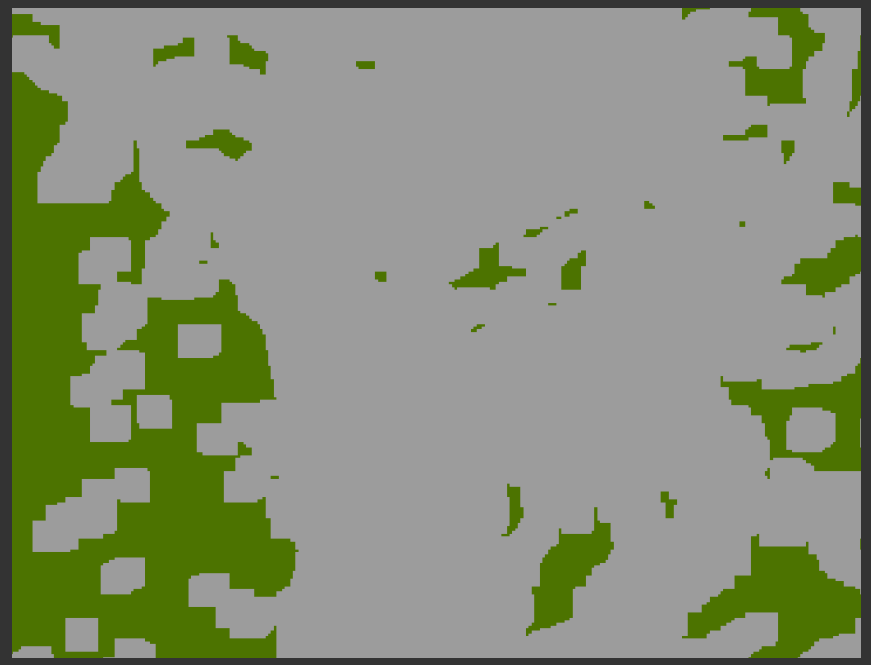


Green expanded by 5 30 m pixels

Shrink

- Shrink a specific category in a categorical raster by a specified number of cells by replacing them with the values of the cell that is most frequent in its neighborhood

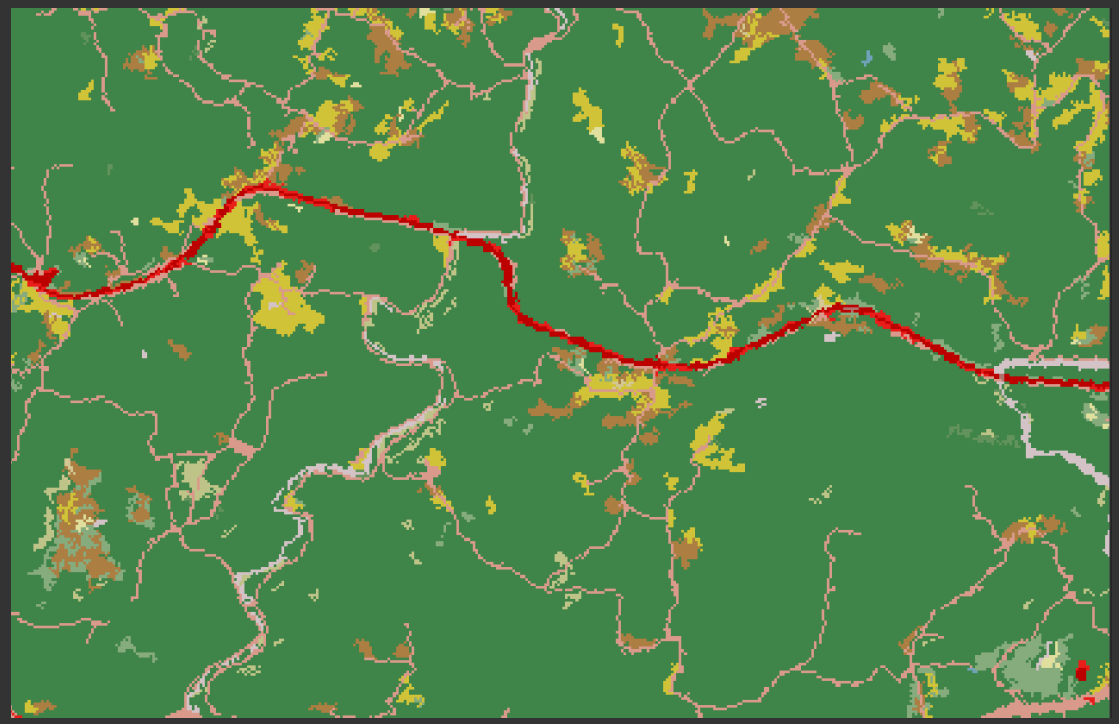


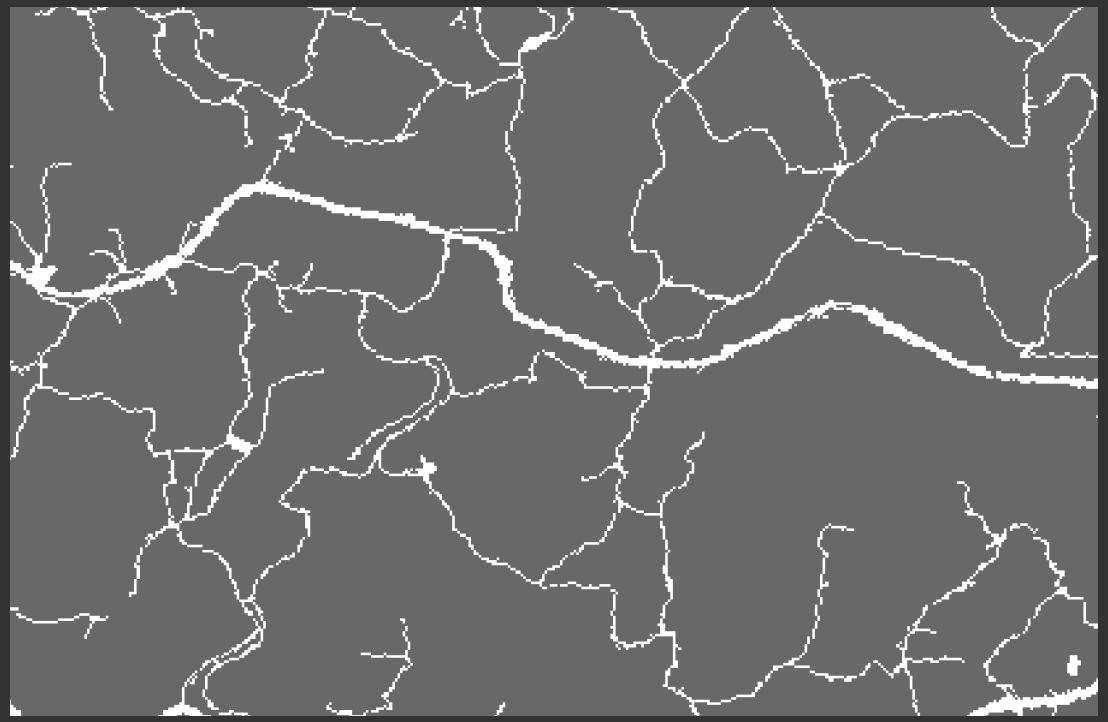


Green shrank by 5 30 m pixels and replaced with gray

Nibble

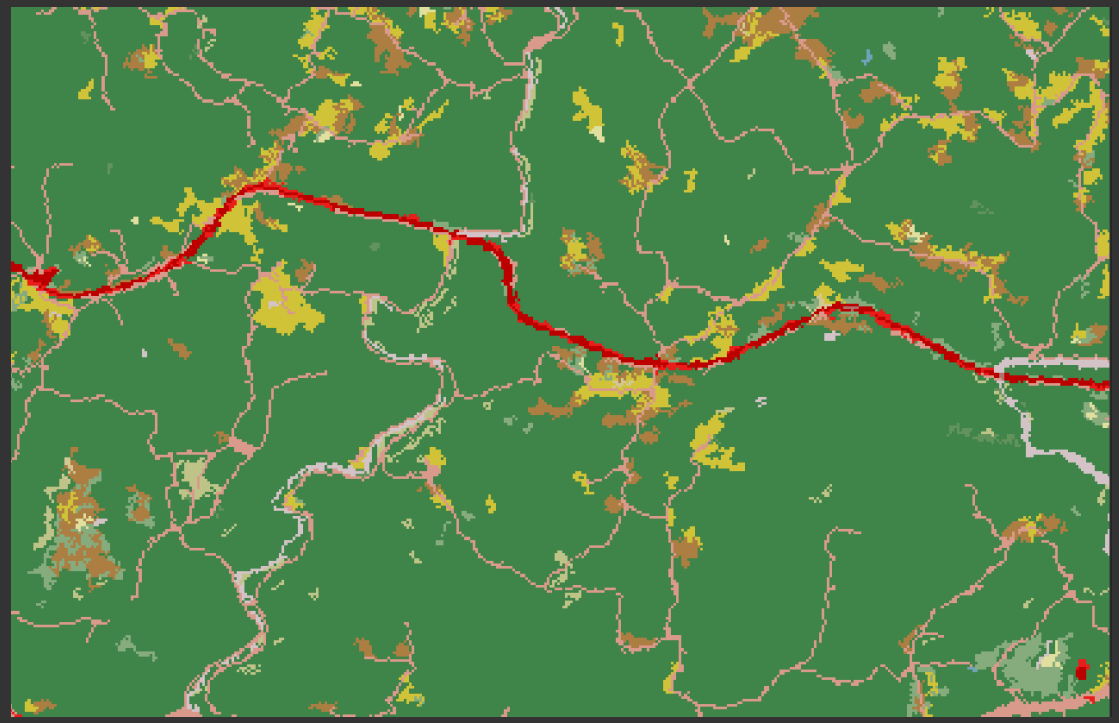
- Replace cells of a raster corresponding to a mask with the values of the nearest neighbor

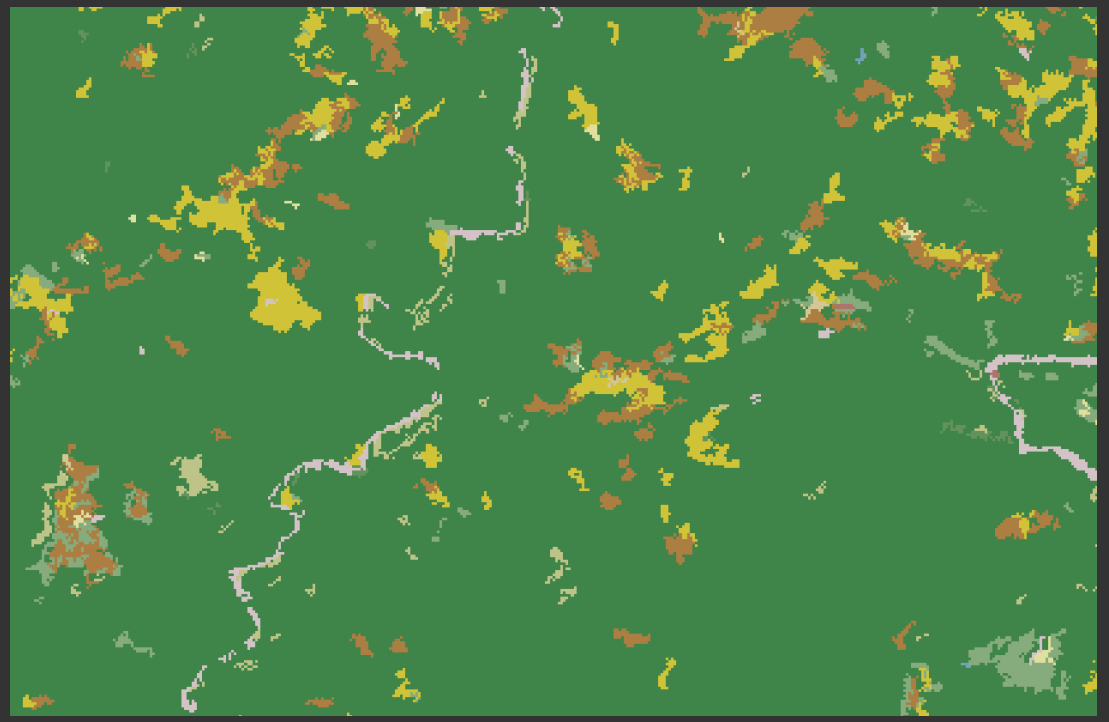




Nibble

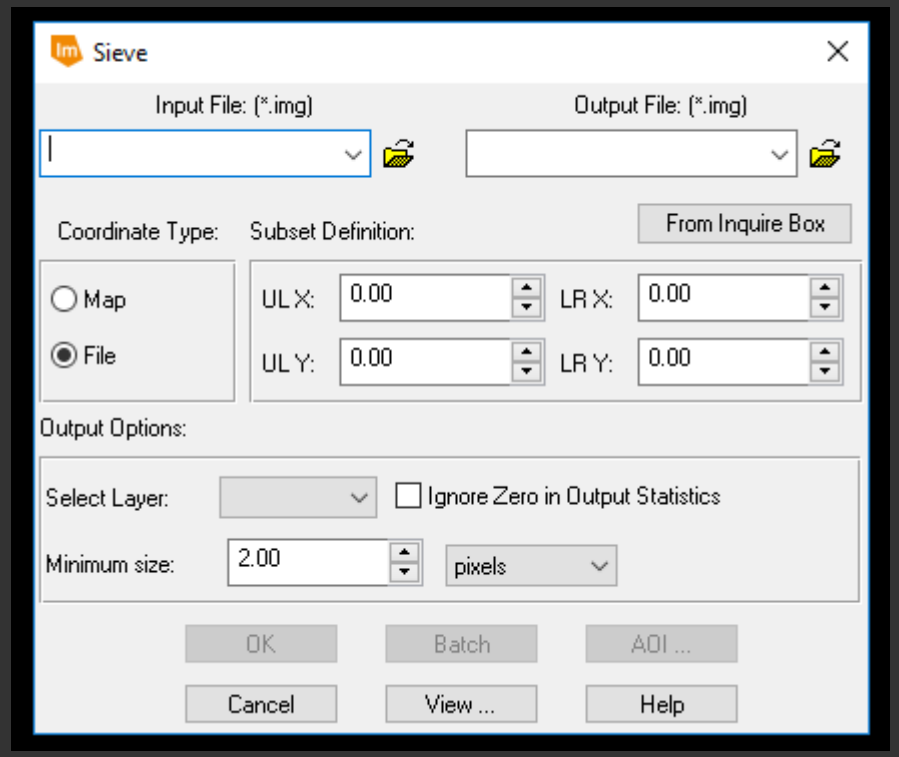
- Replace cells of a raster corresponding to a mask with the values of the nearest neighbor





Sieving

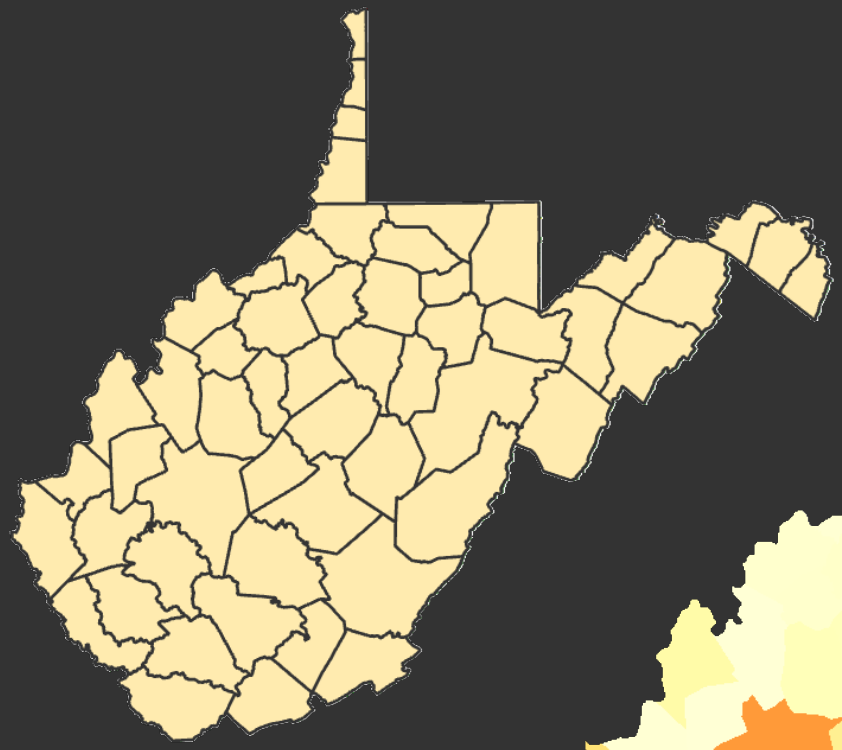
- Replace regions smaller than a certain size in a categorical raster with the surrounding class
- Can be used to approximate a minimal mapping unit (MMU)

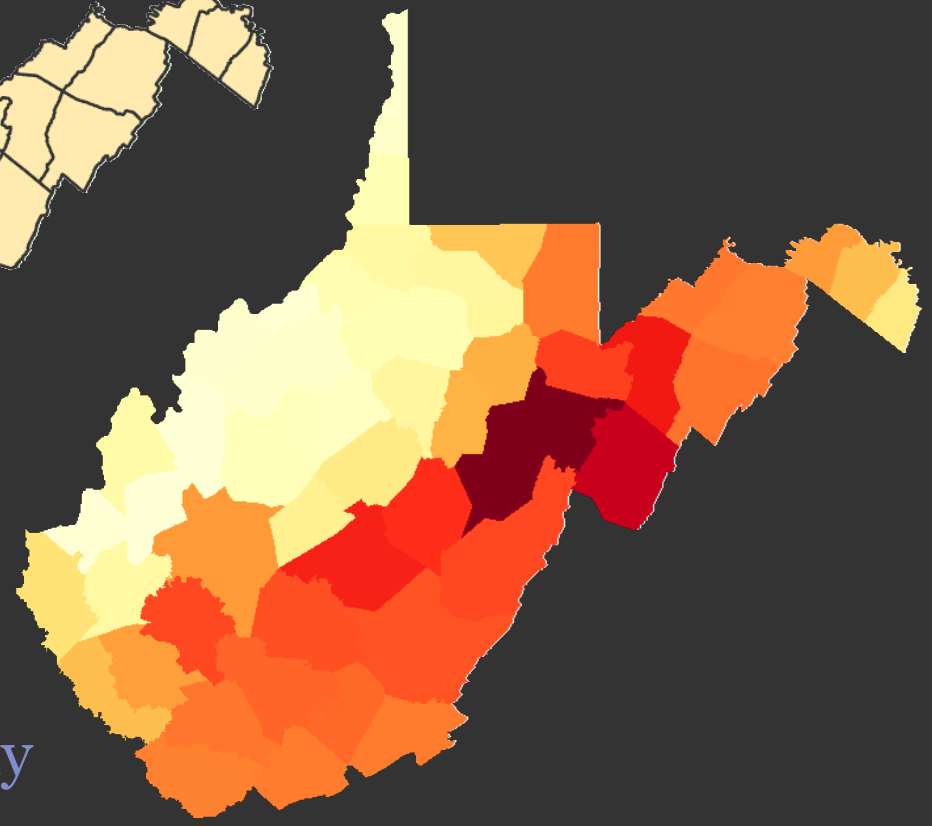


Raster Summarization

Zonal Statistics

- Used to obtain statistics from a continuous raster within an area or zone as defined by another raster or a polygon vector layer
- Can obtain results as a raster surface for a single statistic





Elevation range by county

Zonal Statistics as Table

- Used to obtain statistics from a continuous raster within an area or zone as defined by another raster or a polygon vector layer
- Can obtain multiple statistics as a table: mean, majority, maximum, median, minimum, minority, range, standard deviation, sum, and variety
- Can use table join to join the results back to the zone data

NAME	ZONE_CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	VARIETY	MAJORITY	MINORITY	MEDIAN
Ohio	1	313037	281733300	190	434	244	335.185646	53.554422	104925509	245	190	433	349
Marshall	2	896296	806666400	181	488	307	346.481389	58.372259	310549883	308	190	181	361
Preston	3	1872347	1685112300.000001	257	1047	790	626.009406	122.181059	1172106833	791	542	257	606
Morgan	4	661649	595484100	0	711	711	278.286232	97.964891	184127807	606	261	0	260
Monongalia	5	1052070	946863000	214	788	574	404.379005	94.363254	425435020	561	265	214	381
Wetzel	6	1038769	934892100	170	518	348	356.66806	61.03432	370495724	346	380	170	365
Mineral	7	947525	852772500	167	960	793	399.815696	179.897201	378835367	794	262	167	332
Berkeley	8	925921	833328900	69	664	595	201.454417	81.850591	186530875	596	156	71	174
Marion	9	895803	806222700	249	612	363	374.991877	51.121075	335918848	361	363	249	372
Tyler	10	749712	674740800	158	471	313	288.145992	44.391612	216026508	303	290	159	289
Hampshire	11	1854635	1669171500.000001	143	924	781	378.330457	114.098121	701664907	779	354	143	362
Jefferson	12	608694	547824600	71	520	449	164.008096	43.217139	99830744	447	162	72	159
Pleasants	13	386824	348141600	165	381	216	269.91643	42.829357	104410153	217	179	165	276
Harrison	14	1198449	1078604100	258	559	301	363.909574	39.328835	436127065	301	354	258	361
Taylor	15	505225	454702500	256	636	380	414.409028	58.841298	209369801	381	356	257	409

Elevation statistics by county

Tabulate Area

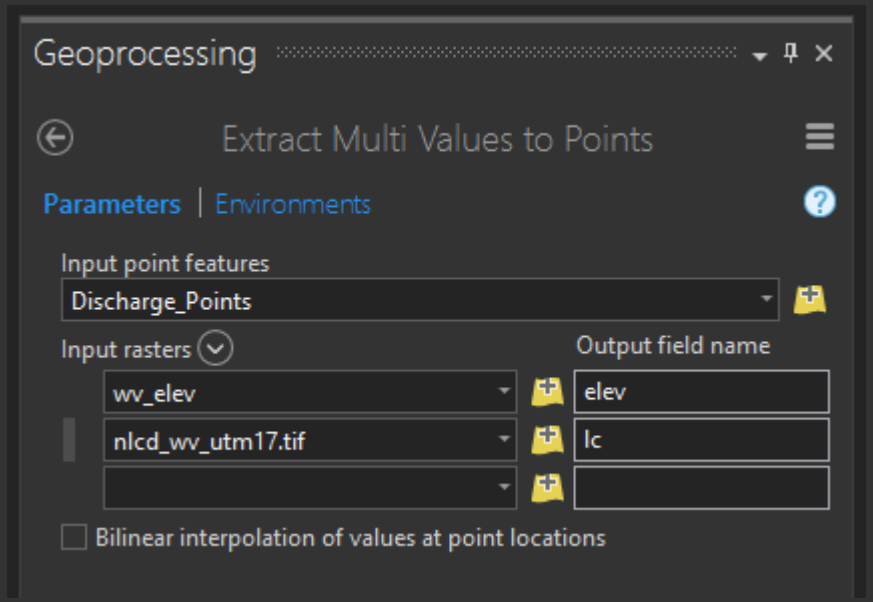
- Used to obtain areas for categories in a categorical raster within an area or zone as defined by another raster or polygon vector layer
- Areas will be in square map units
- Can use table join to join the results back to the zone data

NAME	VALUE_11	VALUE_21	VALUE_22	VALUE_23	VALUE_24	VALUE_31	VALUE_41	VALUE_42	VALUE_43	VALUE_52	VALUE_71	VALUE_81	VALUE_82	VALUE_90	VALUE_95
Ohio	7220700	32448600	12725100	9791100	4060800	1828800	163184400	243900	27000	5400	5736600	33041700	11615400	10800	5400
Marshall	17972100	52911900	8149500	7511400	3639600	2680200	594241200	1294200	90000	61200	17165700	90684900	10204200	368100	233100
Preston	12051000	109386000	8920800	5368500	1096200	11108700	1264432500	23017500	12316500	691200	2385900	173321100	58838400	1421100	1750500
Morgan	5271300	38037600	5807700	919800	235800	339300	448716600	15448500	14912100	1154700	1809000	57774600	4842000	153900	11700
Monongalia	16850700	75492900	25077600	17461800	5606100	6173100	688201200	1125900	1607400	403200	10475100	74536200	23842800	216000	14400
Wetzel	7335900	48271500	5332500	2608200	595800	570600	832127400	1025100	86400	146700	6072300	23953500	6749100	71100	18900
Mineral	7317900	51754500	9358200	4086900	863100	3462300	625183200	14517900	18436500	1299600	2419200	110389500	3740400	216000	113400
Berkeley	5900400	57793500	40197600	11976300	4634100	1073700	387274500	19776600	16367400	1209600	3294900	257097600	23208300	2637900	891000
Marion	7502400	64860300	17891100	8419500	2449800	2124900	618721200	819000	654300	75600	7243200	58851000	16449300	9900	29700
Tyler	11124000	31230900	2791800	820800	271800	66600	556369200	4665600	219600	117000	3649500	53750700	9626400	40500	22500
Hampshire	13815900	46972800	7014600	1631700	397800	535500	1241870400	43697700	69669000	4070700	4116600	234529200	1488600	62100	59400
Jefferson	9701100	59721300	18992700	5191200	1332000	877500	112617000	24759900	8029800	481500	1954800	268405200	31912200	2241000	2356200
Pleasants	13662900	21668400	3581100	1895400	518400	375300	276406200	5797800	348300	194400	2730600	18234000	2688300	0	133200
Harrison	6086700	81247500	29097000	16684200	4040100	6741900	757297800	470700	2953800	93600	6548400	156815100	10492200	20700	39600
Taylor	8799300	33958800	5025600	1863900	459900	1993500	329850000	334800	882000	0	1338300	65516400	4537800	4500	152100

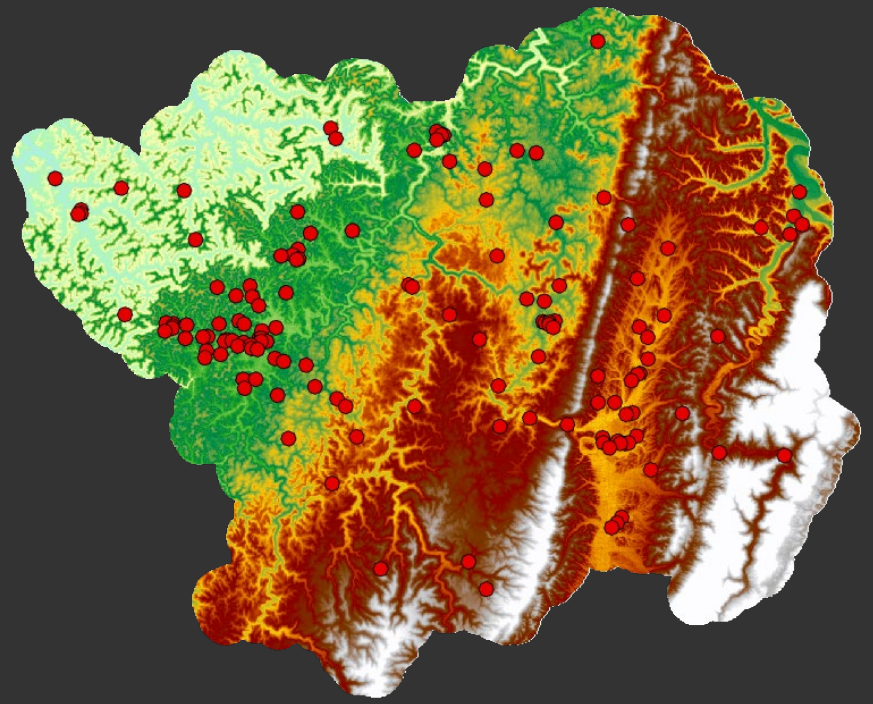
Area of land cover by county

Extract Values to Points

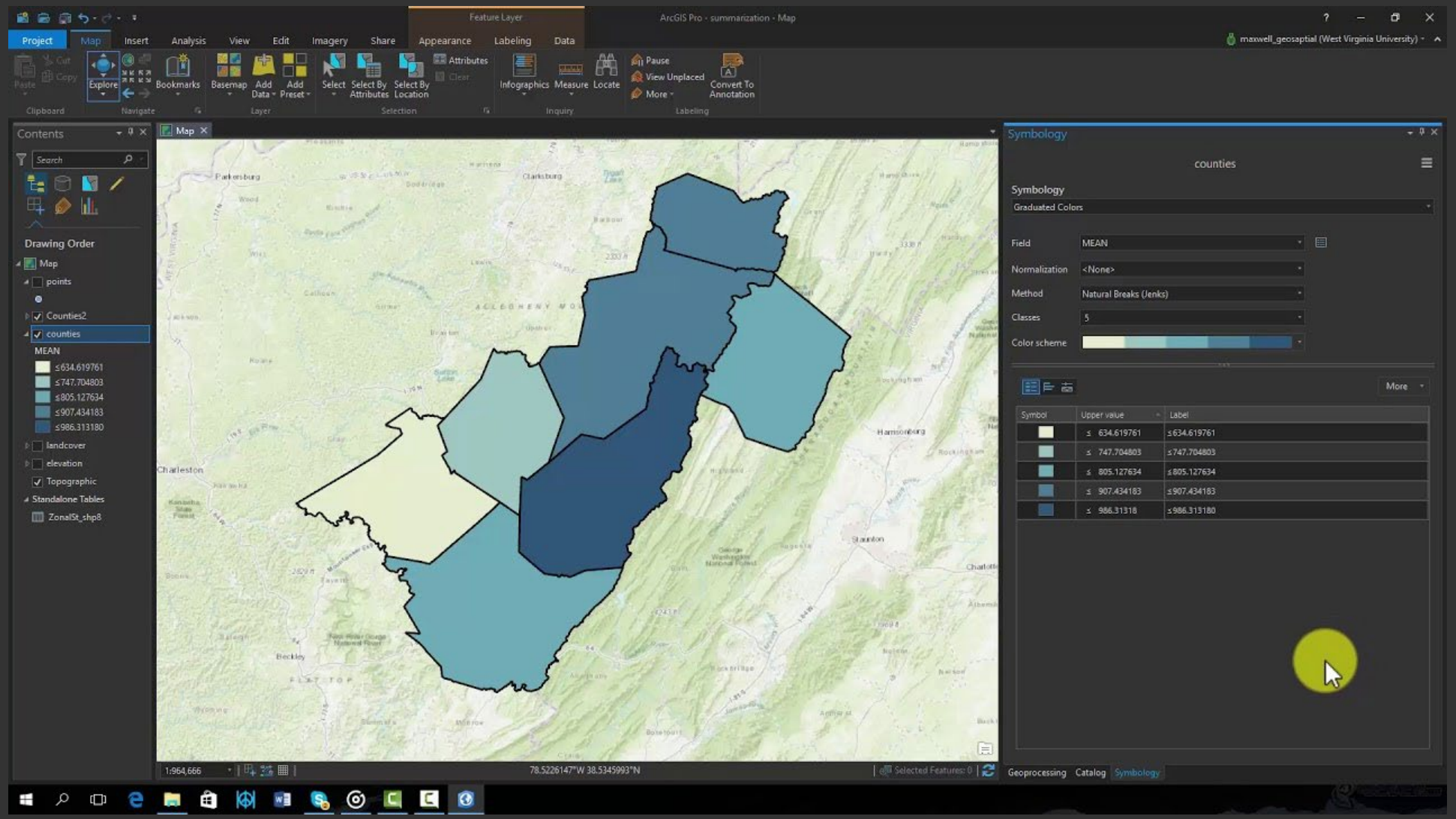
- Extract raster values at point locations and add the data to the attribute table
- Can use Extract Multi Values to Points Tool or Extract Values to Points Tool



E	elev	lc
1	457	21
1	365	41
1	400	41
1	395	23
1	402	81
1	329	81
1	398	23
1	469	41
1	474	41
1	485	81
1	444	23
1	510	21
1	299	81
1	377	81
1	348	41



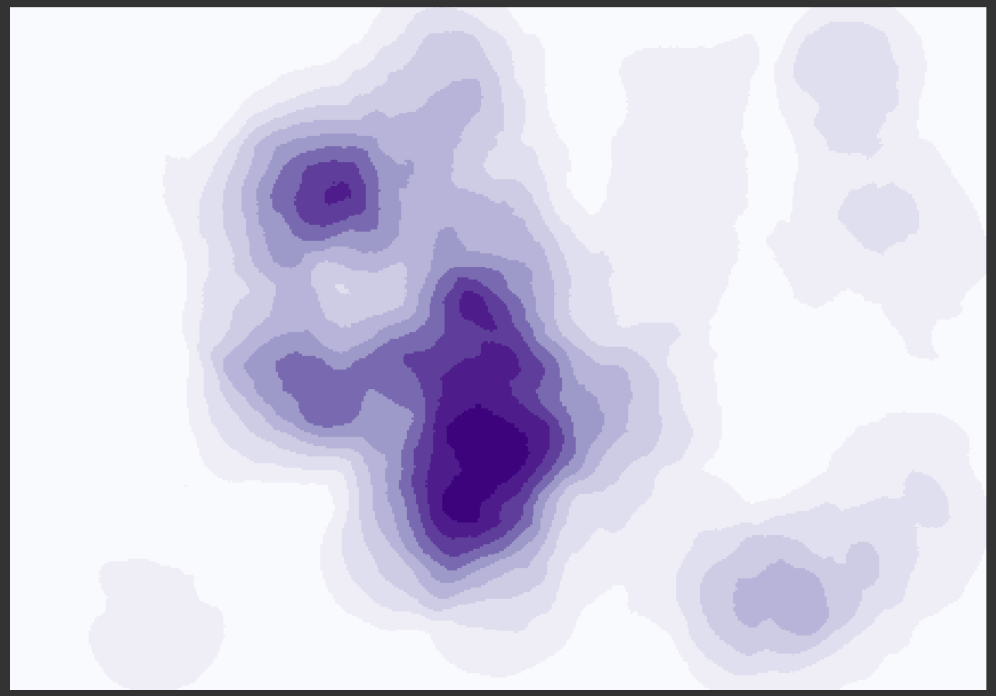
Video: Raster Summarization



Estimating Densities

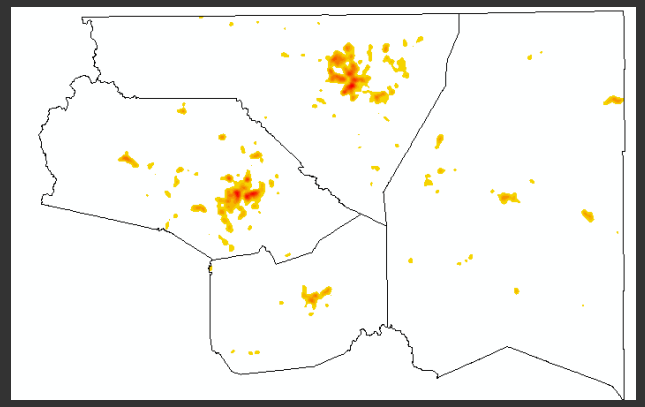
Point Density/Line Density

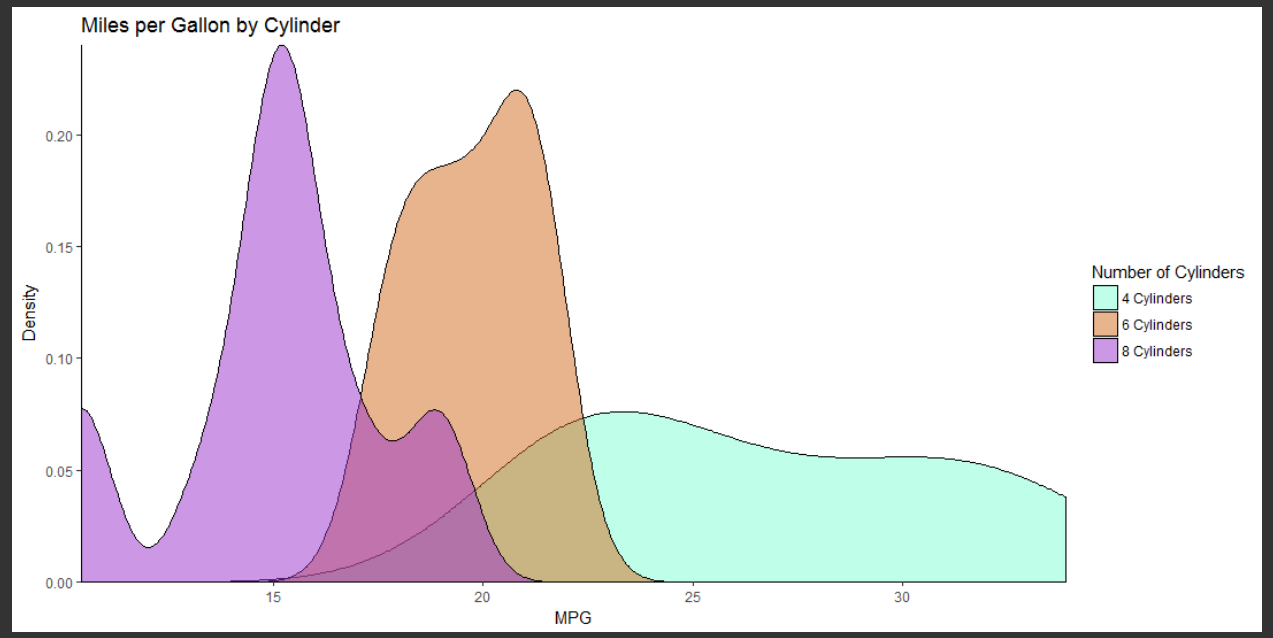
- Calculates the magnitude per unit area for point or line features that fall within a neighborhood around each cell
- Line length/area
- Number of points/area
- Can incorporate weights
- Must specify neighborhood shape and size

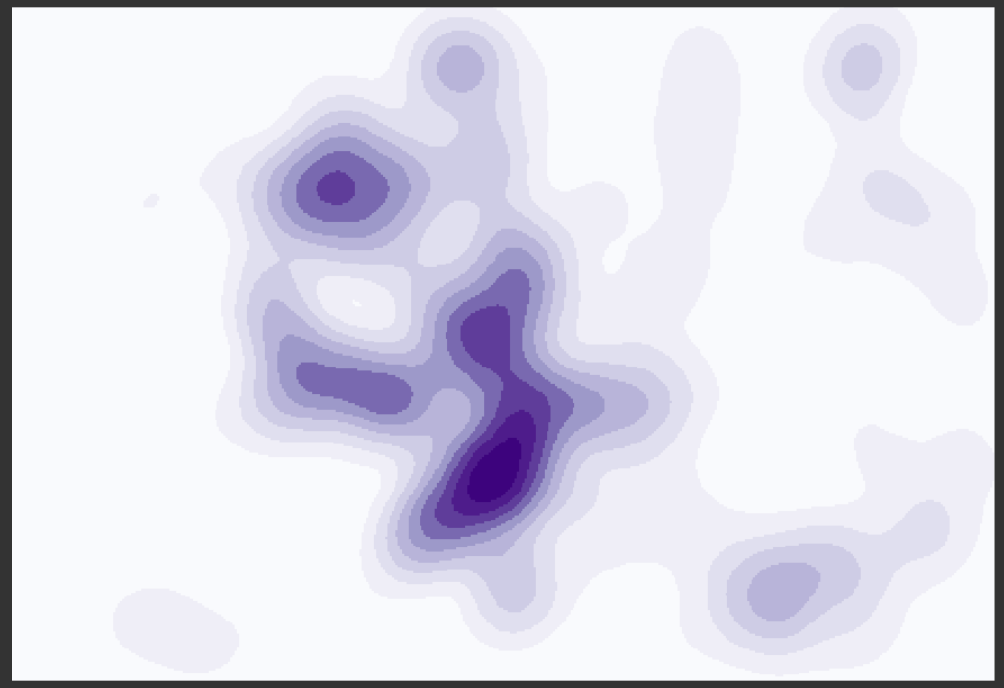


Kernel Density

- Fits a kernel density function to estimate density



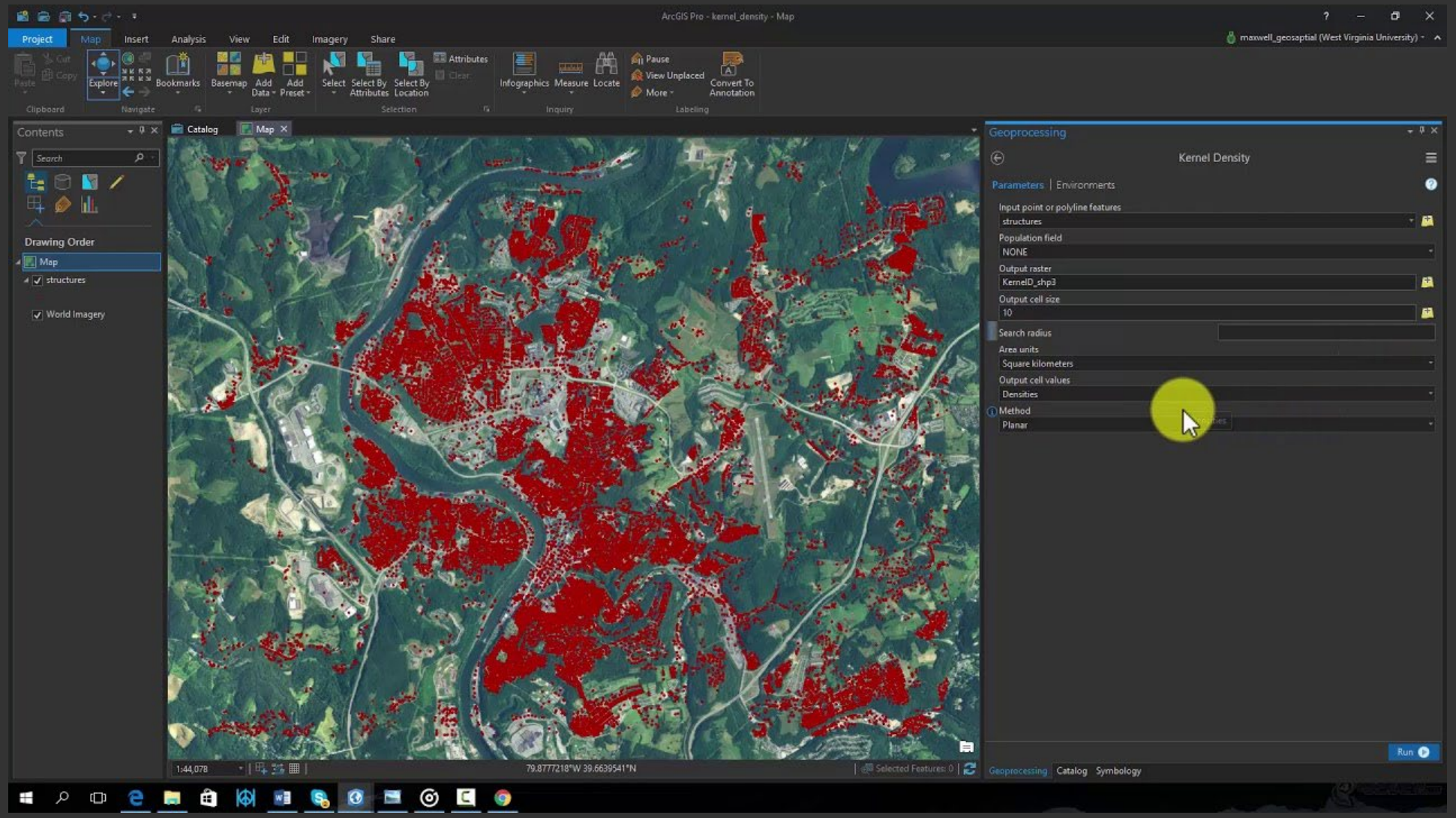




Point Density vs. Kernel Density

- In point and line density, a neighborhood is specified that calculates the density of the population around each output cell.
- Kernel density spreads the known quantity of the population for each point out from the point location.
- The resulting surfaces surrounding each point in kernel density are based on a quadratic formula with the highest value at the center of the surface (the point location) and tapering to zero at the search radius distance. For each output cell, the total number of the accumulated intersections of the individual spread surfaces is calculated.

Video: Density Estimation



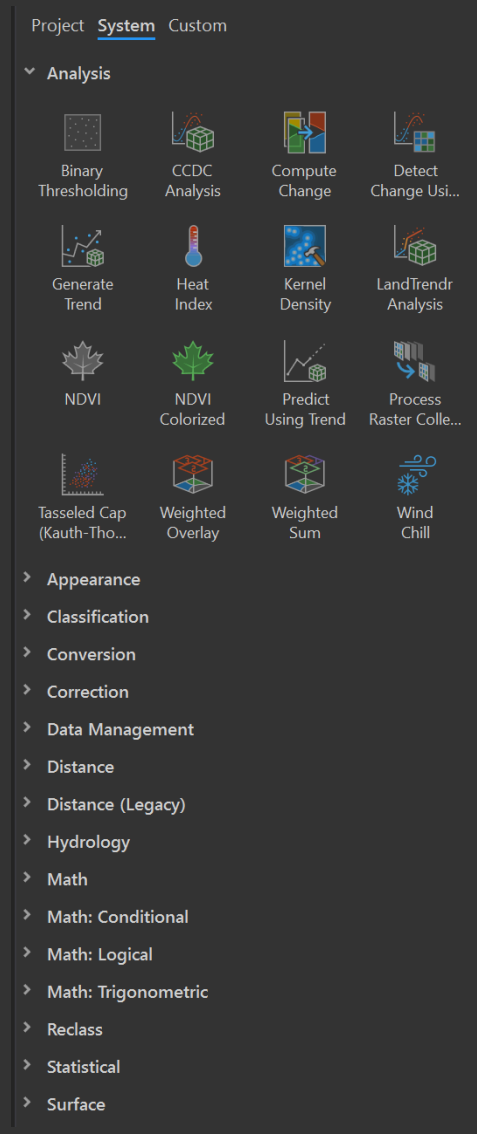
Spatial Analysis Tools

Software Options

- ArcGIS Pro
- ArcMap
- Erdas Imagine
- ITT ENVI
- QGIS/GRASS/SAGA
- R

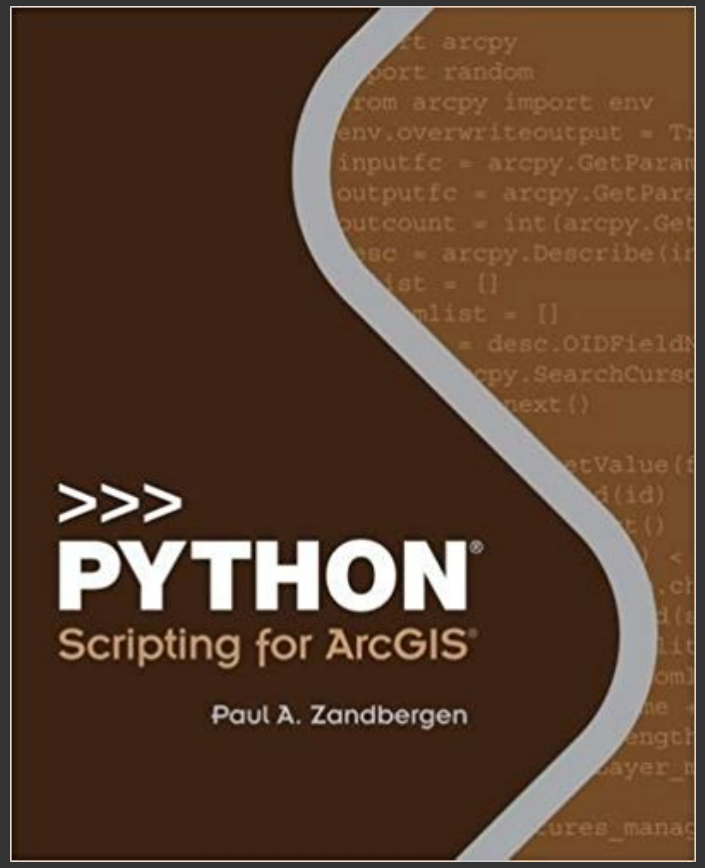
Logos were obtained from organization websites.

Raster Functions



- Different way to analyze raster data
- Results not saved to disk
- Virtual raster data in memory
- Recalculate with changing scales and/or extents

ArcPy Python

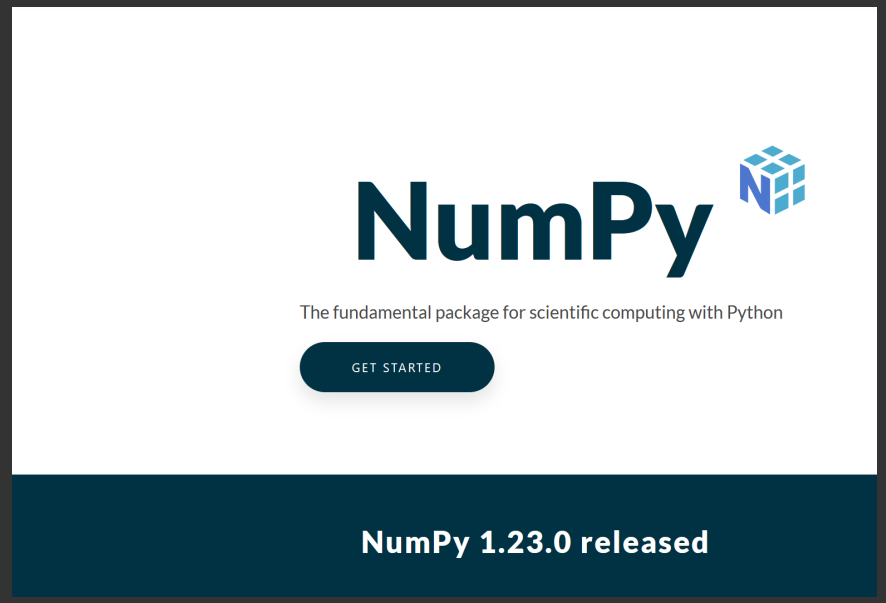


https://esripress.esri.com/display/index.cfm?fuseaction=display&websiteID=276&moduleID=0

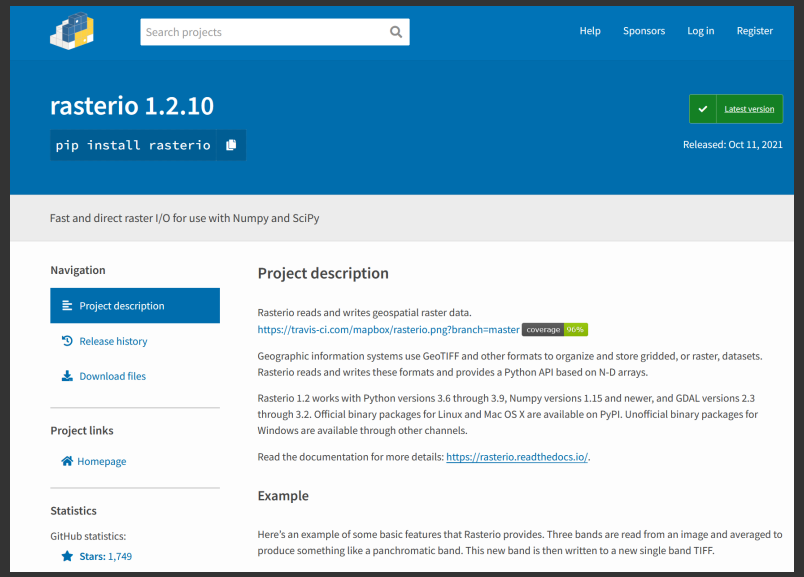
```
class LicenseError(Exception):
    pass

class SpatialRefProjError (Exception):
    pass


import arcpy
from arcpy import env
from arcpy.sa import *
import os
import arcpy.mapping as mapping

try:
        #Check for spatial analyst license
    if arcpy.CheckExtension("Spatial") == "Available":
        arcpy.CheckOutExtension("Spatial")
    else:
        raise LicenseError
    demRaster = arcpy.GetParameterAsText(0)
    dscRaster = arcpy.Describe(demRaster)

    if dscRaster.spatialReference.type != "Projected":
        raise SpatialRefProjError


    # Set overwrite option
    env.overwriteOutput = True
    #Set extent based on users input
    ext = arcpy.GetParameterAsText(2)
    if ext == "DEFAULT" or ext == "MAXOF" or ext == "MINOF":
        env.extent = dscRaster.extent
    else:
        env.extent = ext

    analysisWindow = arcpy.GetParameterAsText(1)
```

Script by Jeff Evans

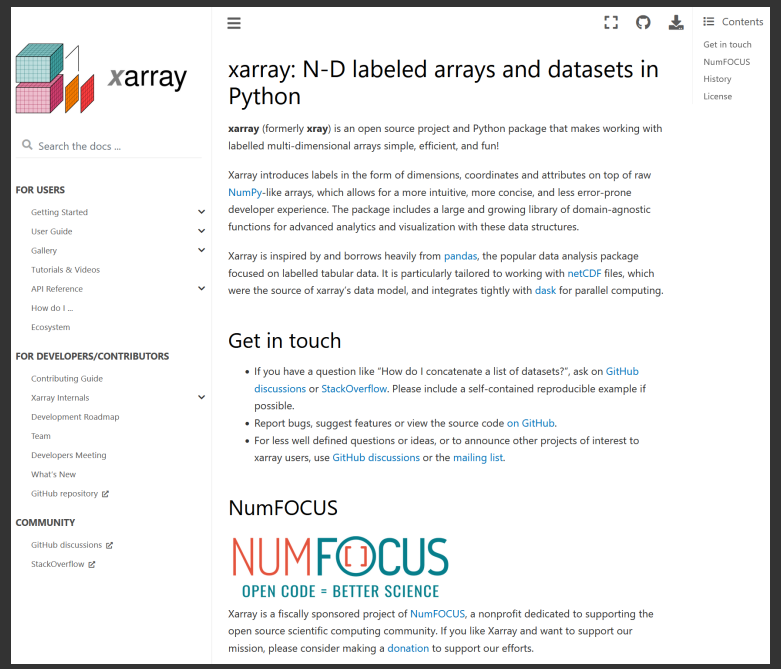
Open-Source Python



https://numpy.org/

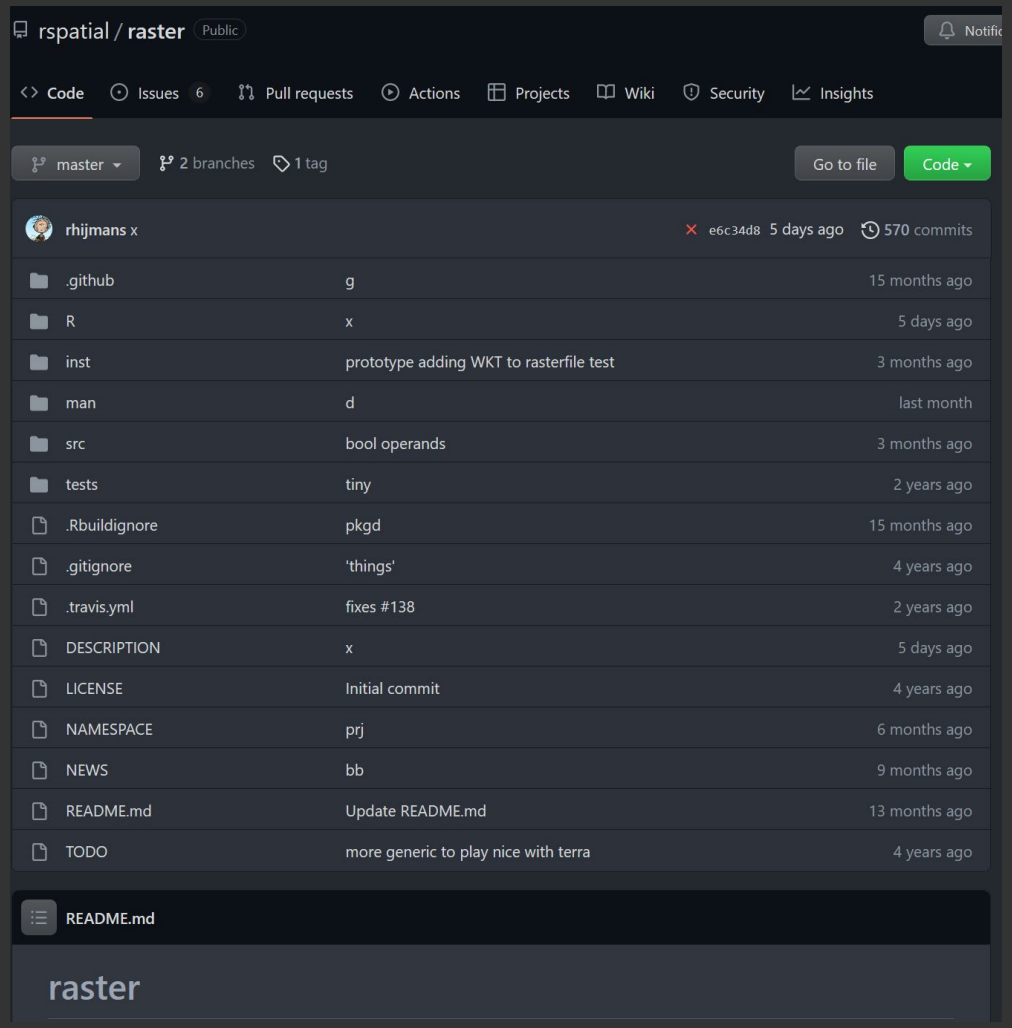


https://pypi.org/project/rasterio/



https://docs.xarray.dev/en/stable/index.html

R



https://github.com/rspatial/raster

https://github.com/rspatial/terra

QGIS

- Raster analysis
  - Cell statistics
  - Equal to frequency
  - Fuzzify raster (gaussian membership)
  - Fuzzify raster (large membership)
  - Fuzzify raster (linear membership)
  - Fuzzify raster (near membership)
  - Fuzzify raster (power membership)
  - Fuzzify raster (small membership)
  - Greater than frequency
  - Highest position in raster stack
  - Less than frequency
  - Lowest position in raster stack
  - Raster boolean AND
  - Raster boolean OR
  - Raster calculator
  - Raster layer statistics
  - Raster layer unique values report
  - Raster layer zonal statistics
  - Raster surface volume
  - Reclassify by layer
  - Reclassify by table
  - Rescale raster
  - Round raster
  - Sample raster values
  - Zonal histogram
  - Zonal statistics

- Raster analysis
  - Accumulated cost
  - Accumulated cost (anisotropic)
  - Accumulated cost (isotropic)
  - Accumulation functions
  - Aggregation index
  - Analytical hierarchy process
  - Covered distance
  - Cross-classification and tabulation
  - Diversity of categories
  - Fragmentation (alternative)
  - Fragmentation (standard)
  - Fragmentation classes from density and connectivity
  - Imcorr - feature tracking
  - Layer of extreme value
  - Least cost paths
  - Ordered weighted averaging
  - Pattern analysis
  - Soil texture classification

- Raster extraction
  - Clip raster by extent
  - Clip raster by mask layer
  - Contour
  - Contour Polygons

- Raster visualization
  - Aspect-slope grid
  - Histogram surface
  - Rgb composite
  - Terrain map view

- Raster tools
  - Aggregate
  - Average with mask 1
  - Average with mask 2
  - Average with thereshold 1
  - Average with thereshold 2
  - Average with thereshold 3
  - Change data storage
  - Close gaps
  - Close gaps with spline
  - Close gaps with stepwise resampling
  - Close one cell gaps
  - Constant grid
  - Convert data storage type
  - Crop to data
  - Destriping
  - Destriping with mask
  - Directional average
  - Invert data/no-data
  - Invert grid
  - Mirror grid
  - Mosaic raster layers
  - Patching
  - Proximity raster
  - Raster buffer
  - Raster cell index
  - Raster masking
  - Raster orientation
  - Raster proximity buffer
  - Reclassify values
  - Reclassify values (range)
  - Reclassify values (simple)
  - Reclassify values (single)
  - Reclassify values (table)
  - Resampling
  - Shrink and expand
  - Split RGB bands
  - Threshold raster buffer
  - Transpose raster layers

- Raster (r.*)
  - r.basins.fill
  - r.blend.combine
  - r.blend.rgb
  - r.buffer
  - r.buffer.lowmem
  - r.carve
  - r.category
  - r.category.out
  - r.circle
  - r.clump
  - r.coin
  - r.colors
  - r.colors.out
  - r.colors.stddev
  - r.composite
  - r.contour
  - r.cost
  - r.covar
  - r.cross
  - r.describe
  - r.distance
  - r.drain
  - r.fill.dir
  - r.fill.stats
  - r.fillnulls
  - r.flow
  - r.geomorphon
  - r.grow
  - r.grow.distance
  - r.gwflow

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.