UNIVERSITETET I OSLO

GEO3460 – Geografiske informasjonssystemer (GIS) og geografisk datainnsamling – vår 2025

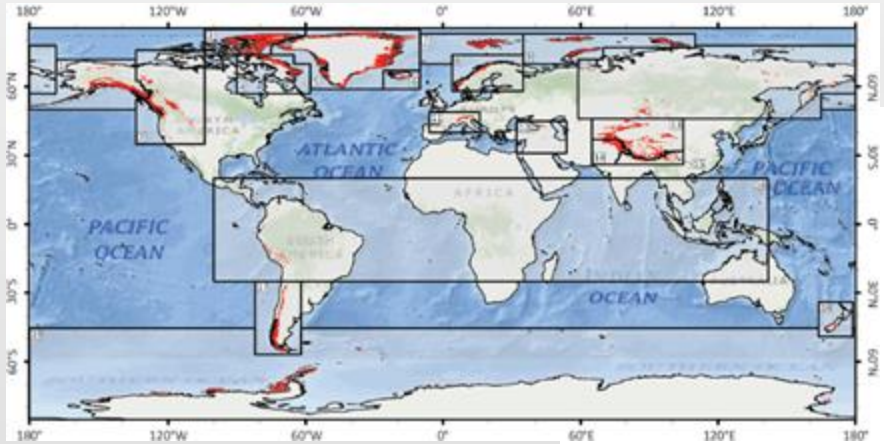
GEO3460 - Geographical Information Systems (GIS) and Geographical Data Acquisition - spring 2025

Vector analysis

Luc Girod (luc.girod@geo.uio.no)

Based on the lectures by Livia Piermattei and Martin Lund

A simple example



Randolph Glacier Inventory vector file

→Geography question?

- Where are glaciers in Fennoscnadia?
- How many are there??
- In which area are the biggest ones?

GlaciersScandinavia_UTM32N — Features Total: 3410,

GlaciersScandinavia_UTM32N — Features Total: 3410, Filtered: 3410, Selected: 1

	rgi_id	cenlon	cenlat	area_km2	glac_name
1	RGI2000-v7.0-G-08-00195	14,13198198333...	66,55988499999...	55,44778610277...	Austerdalsisen
2	RGI2000-v7.0-G-08-01968	7,099710488446215	61,60295299999...	47,47231005496...	Tunsbergdalsbreen
3	RGI2000-v7.0-G-08-01989	7,123205602262564	61,71520400000...	41,87207253862...	Nigardsbreen
4	RGI2000-v7.0-G-08-00412	13,94537377714...	66,67004500000...	41,23524579053...	Storglombreen nord
5	RGI2000-v7.0-G-08-00389	13,84017719786...	66,65708250000...	36,04856318266...	Engabreen
6	RGI2000-v7.0-G-08-03013	6,361172433326915	59,97769300000...	22,99964369111...	BlomstÃ_lskardsb...
7	RGI2000-v7.0-G-08-03012	6,302678292201465	59,97261050000...	22,59700454911...	Svelgjabreen
8	RGI2000-v7.0-G-08-00620	16,39141664633...	67,12736449999...	21,65469521190...	Salajekna
9	RGI2000-v7.0-G-08-00472	14,37776880855...	66,62746799999...	20,91370707444...	Fingerbreen
10	RGI2000-v7.0-G-08-00563	16,12723682503...	67,26962150000...	20,36466716134...	NULL
11	RGI2000-v7.0-	7,	61,72652850000...	20,22609834706...	FÃ¥berstÃ_lsbr

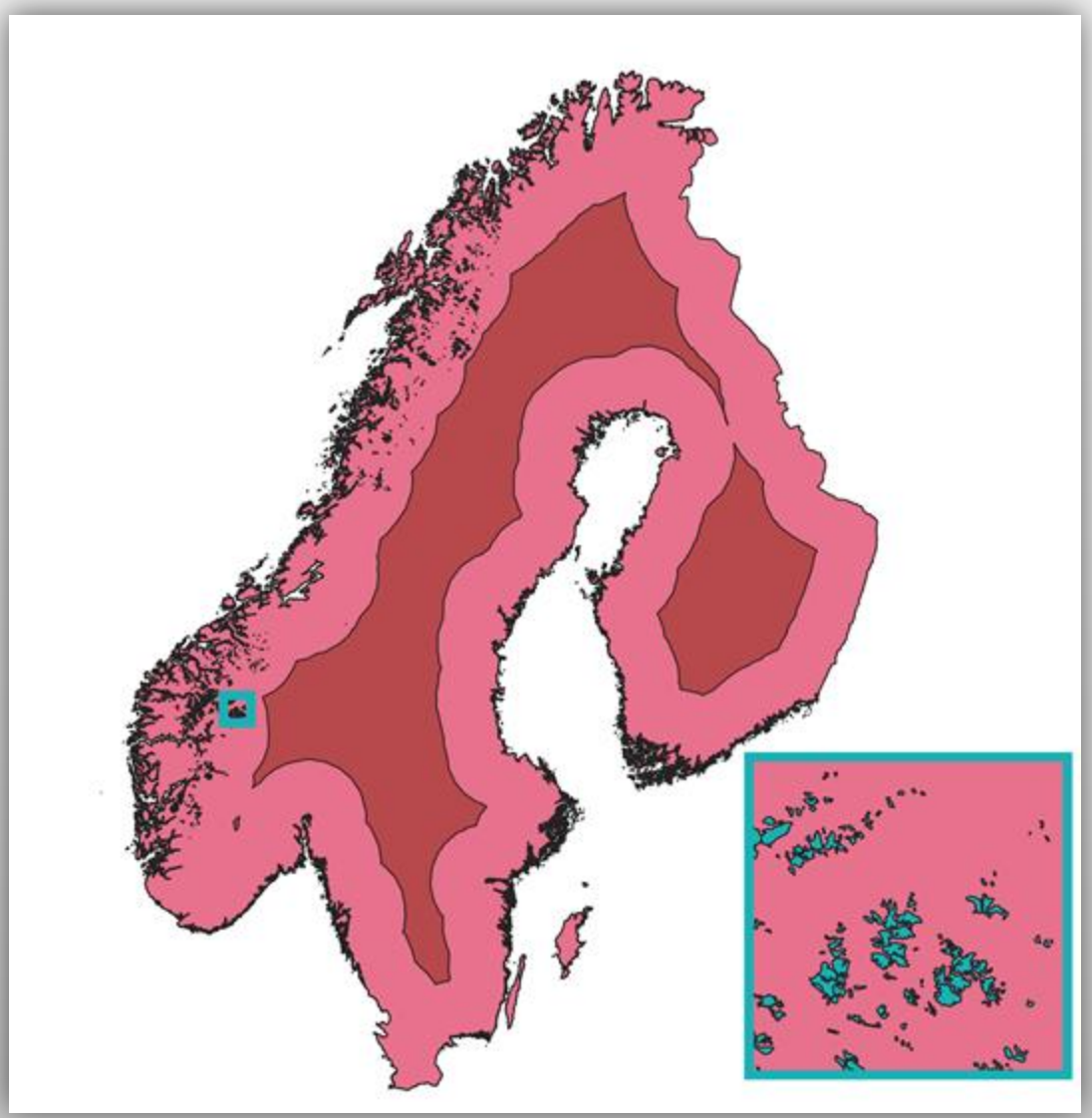
A simple example

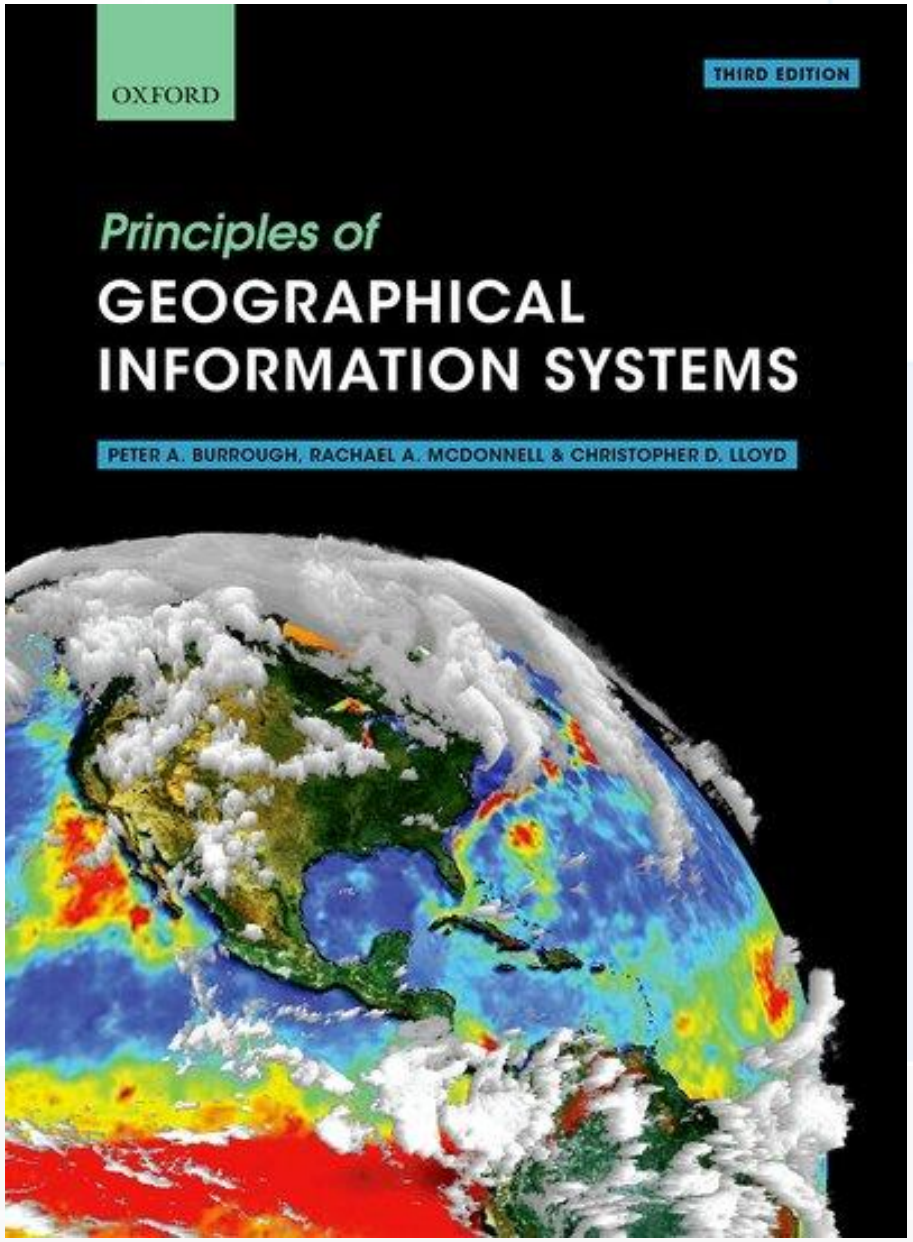
Spatial analysis

- Are there glaciers >50km from the coast?
- Are there glaciers >100km from the coast?

Intersection_50km — Features Total: 353,

Intersection_100km — Features Total: 0,





- Reference text book:

"*Geographical information systems*"

  - Chapter 7

Learning Objectives

1

Conversion between data models

- Rasterization
- Vectorization

2

Geometric operation

(vector)

- Distance
- Buffer
- …

3

Attribute operations

(vector & raster)

- Selection by attribute and location
- Aggregation
- Overlay

Today's topics

Learning Objectives

1

Conversion between data models

- Rasterization
- Vectorization

2

Geometric operation (vector)

- Distance
- Buffer
- …

3

Attribute operations (vector & raster)

- Selection by attribute and location
- Aggregation
- Overlay

Today's topics

Conversion Between Data Models

Recall the difference between raster and vector data…

1. Vector Data Model
Shapefiles (.shp): point, lines, polygons

2. Raster Data Model
. tiff, .img., .asc

Some key differences between the two data models

- Composed of points (or nodes) that have exact location in space
- Points can be singular or can be connected to form polylines or polygons
- Vector data uses sets of coordinates and associated attribute data to define discrete objects
- Vectors will not distort or pixelate, no matter how far we are zoomed in

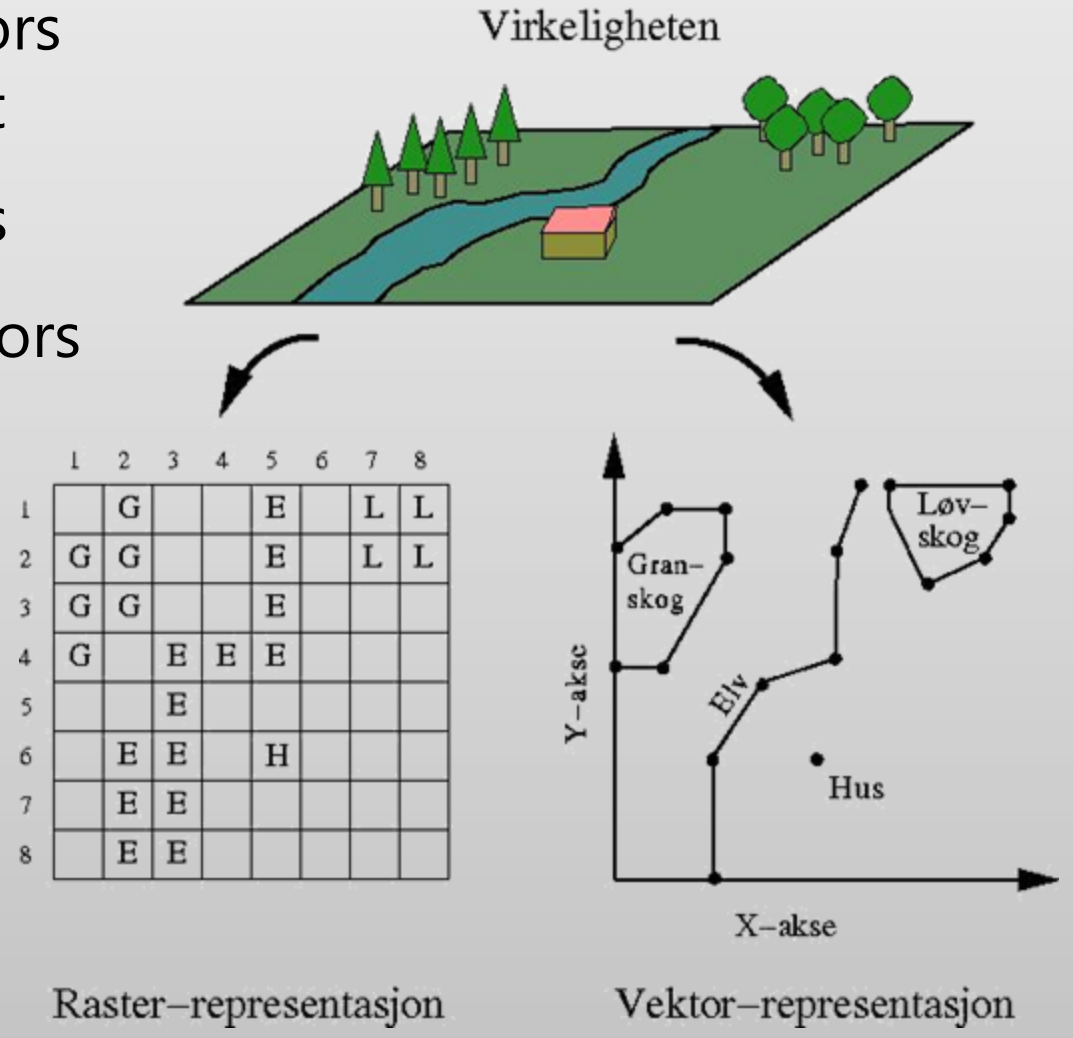
- Composed of cells (or pixels) that have a constant resolution
- Raster can be
  - discrete (e.g. land cover where raster are categorical e.g. urban area = 1 and forest = 2)
  - Continuous: grid cells with gradual changing values e.g. elevation, temperature and remote sensing image
- Because cell size are constant rasters will become pixelated when zoomed-in to very close range

Conversion Between Data Models

You can convert data between raster and vectors but the nature of the data will be very different

- **Rasterization** converts vectors into rasters
- **Vectorization** transforms rasters into vectors

  - …and **how we can convert between these data models** (hint: pushing buttons in ArcGIS)
  - …and **what is actually happening** behind the scenes to make this possible



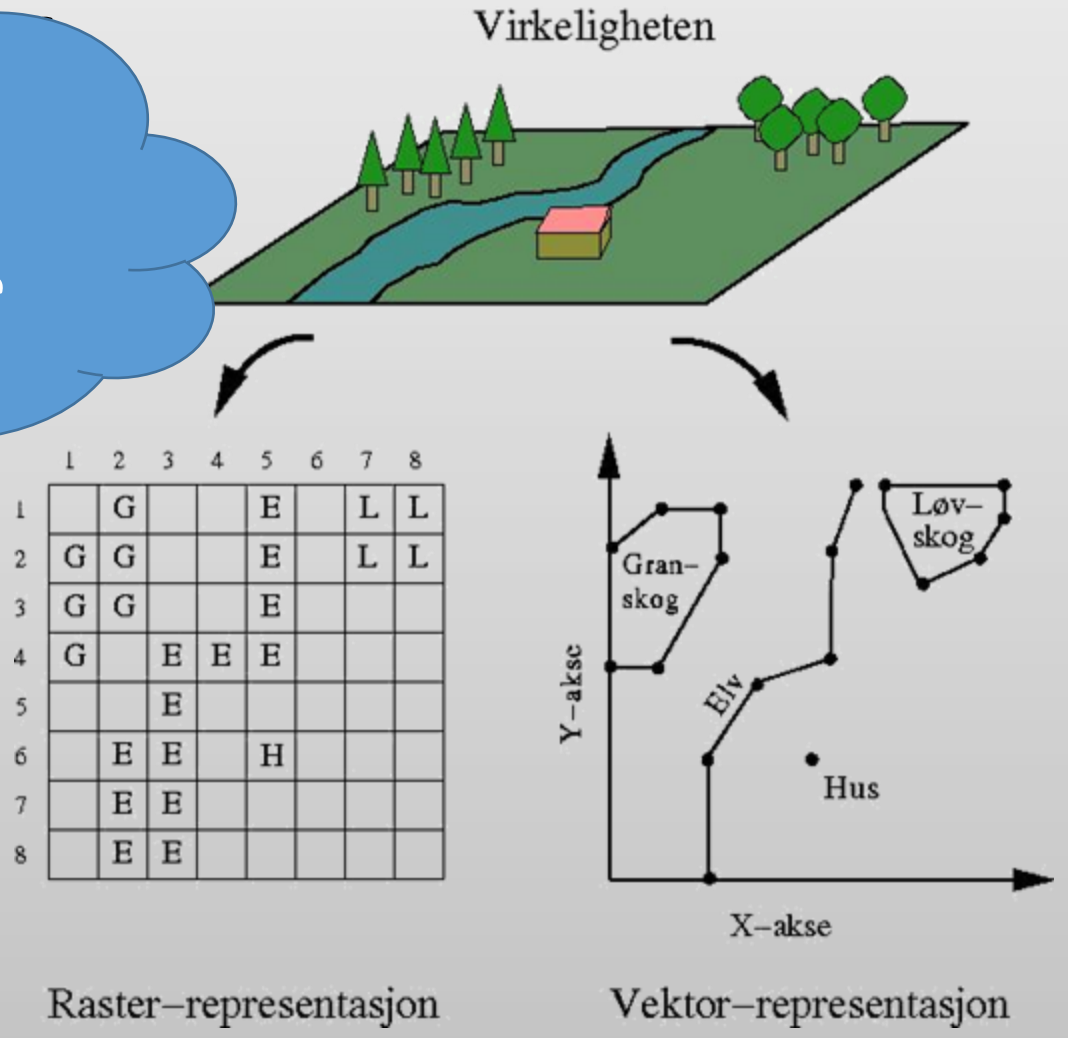
Conversion Between Data Models

You can convert data be
but the nature of the

- **Rasterization** c
- **Vectorization** transf

Why?
The data model we have is not always the data model we want

- …and **how we can convert between these data models** (hint: pushing buttons in ArcMap)
- …and **what is actually happening** behind the scenes to make this possible



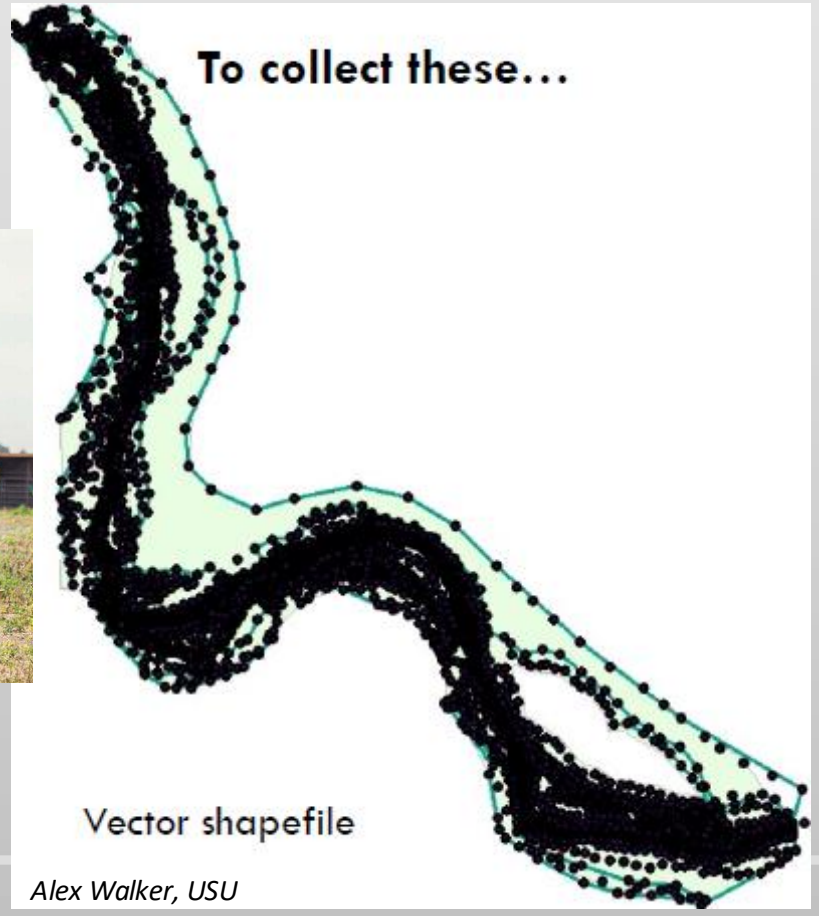
Conversion Between Data Models

- **Rasterization** (convert Vector to Raster)

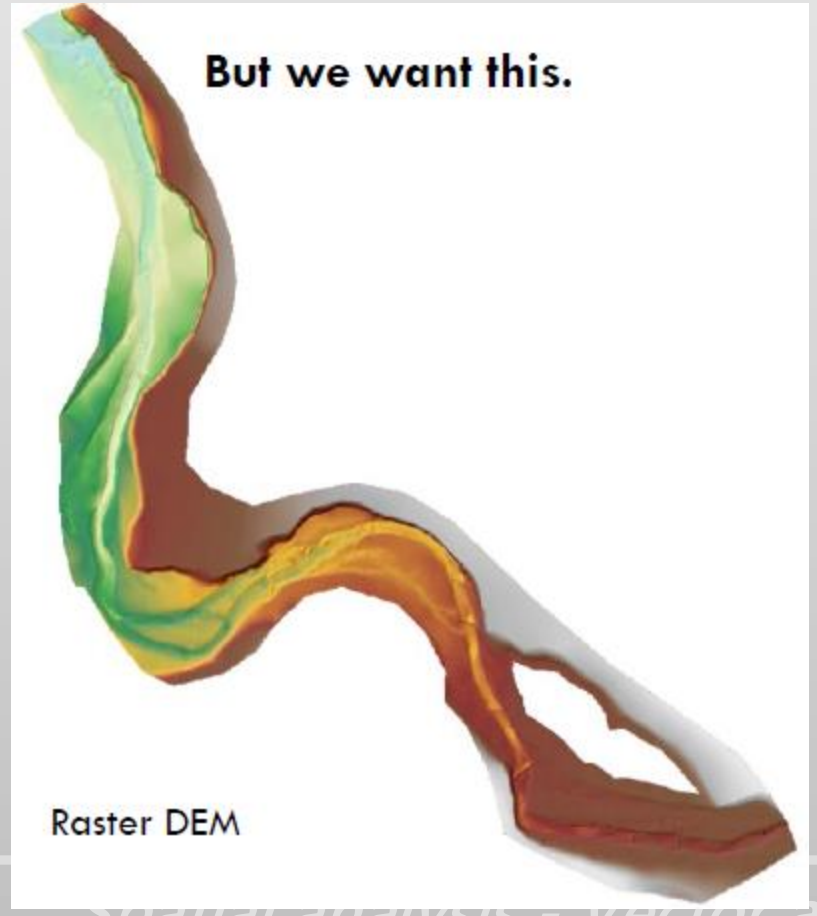
Conversion Between Data Models

- **Rasterization** (convert Vector to Raster): **Point to Raster**
  - the most common data model conversion that you will encounter

Example: to collect elevation information we use this (GPS)…



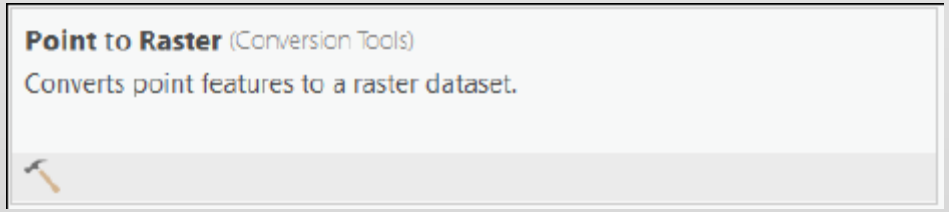
Alex Walker, USU

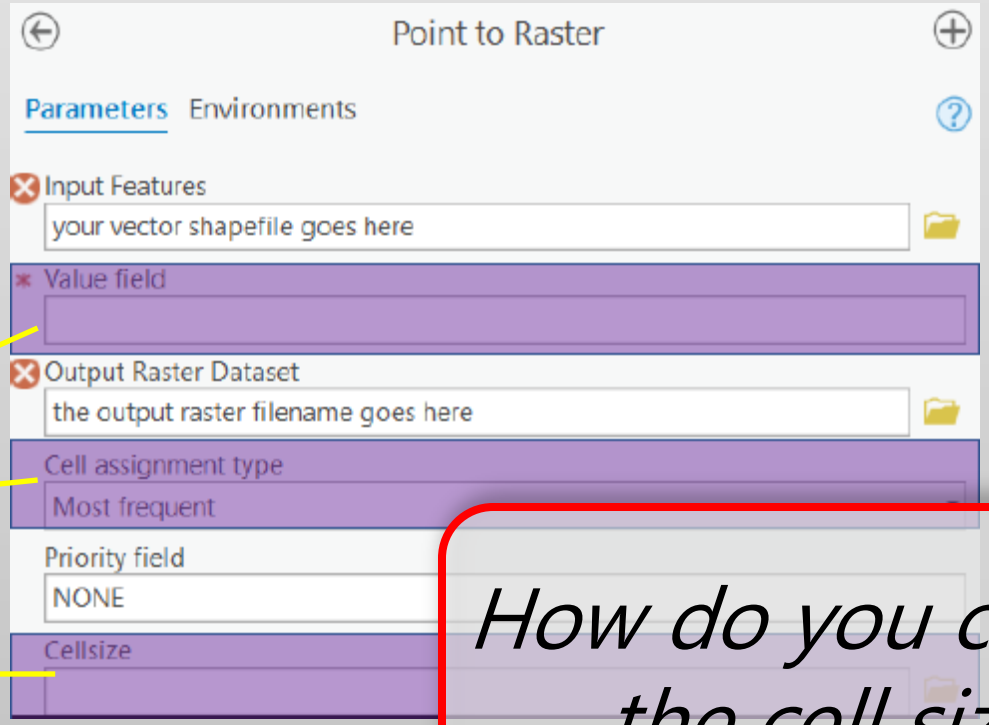


Conversion Between Data Models

- **Rasterization** (convert Vector to Raster): **Point to Raster**
  - the most common data model conversion that you will encounter

Point to Raster conversion tool in ArcPro





The attribute field of the input points

Cell assignment method

cell size (or resolution) of the output raster

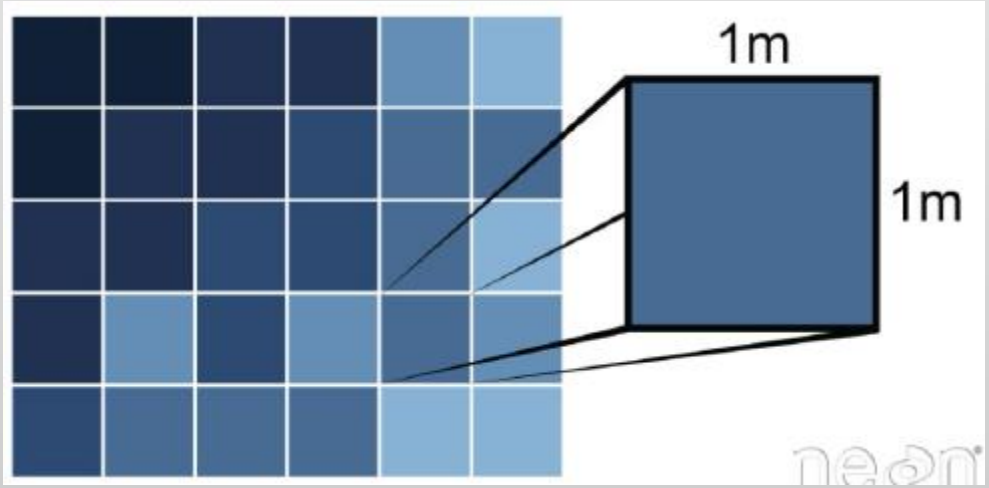
How do you choose the cell size?

https://pro.arcgis.com/en/pro-app/latest/tool-reference/conversion/point-to-raster.htm

Conversion Between Data Models

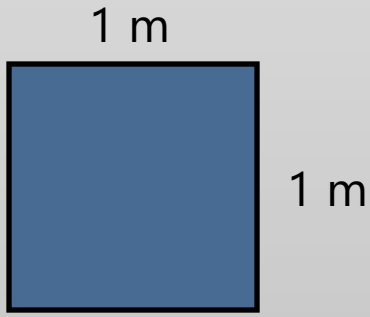
- **Rasterization** (convert Vector to Raster): **Point to Raster**
  - the most common data model conversion that you will encounter

Raster consideration: Resolution

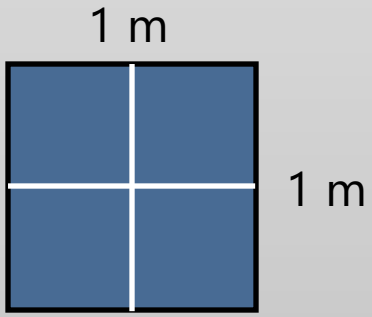


Remember: raster resolution is a tradeoff between the **information you want to convey** and the **size (and processing time)** of the file you are dealing with.

"1 m resolution"



"0.5 m resolution"



To **DOUBLE** the resolution, we have to **QUADRUPLE** the cells. *So be very careful, because files can get really big.*

Conversion Between Data Models

- **Rasterization** (convert Vector to Raster): **Point to Raster**
  - the most common data model conversion that you will encounter

Examples using different options for the cell assignment method in ArcMap

The method to determine how the cell will be assigned a value when more than one feature falls within a cell.

- MOST_FREQUENT –If there is more than one feature within the cell, the one with the most common attribute, in the **Value field**, is assigned to the cell. If they have the same number of common attributes, the one with the lowest FID is used.
- SUM –The sum of the attributes of all the points within the cell (not valid for string data).
- MEAN –The mean of the attributes of all the points within the cell (not valid for string data).
- STANDARD_DEVIATION –The standard deviation of attributes of all the points within the cell. If there are less than two points in the cell, the cell is assigned NoData (not valid for string data).
- MAXIMUM –The maximum value of the attributes of the points within the cell (not valid for string data).
- MINIMUM –The minimum value of the attributes of the points within the cell (not valid for string data).
- RANGE –The range of the attributes of the points within the cell (not valid for string data).
- COUNT –The number of points within the cell.

when more than one feature falls within a cell, which method do you use to assign a value to the cell?

Conversion Between Data Models

- **Rasterization** (convert Vector to Raster): **Point to Raster**
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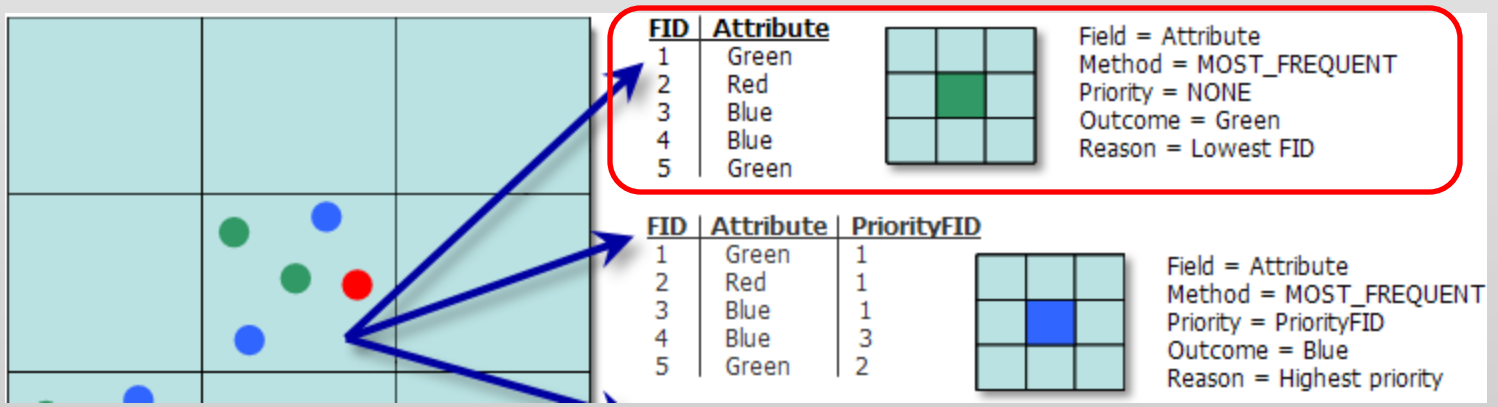

https://pro.arcgis.com/en/pro-app/latest/tool-reference/conversion/point-to-raster.htm

Conversion Between Data Models

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Common methods:

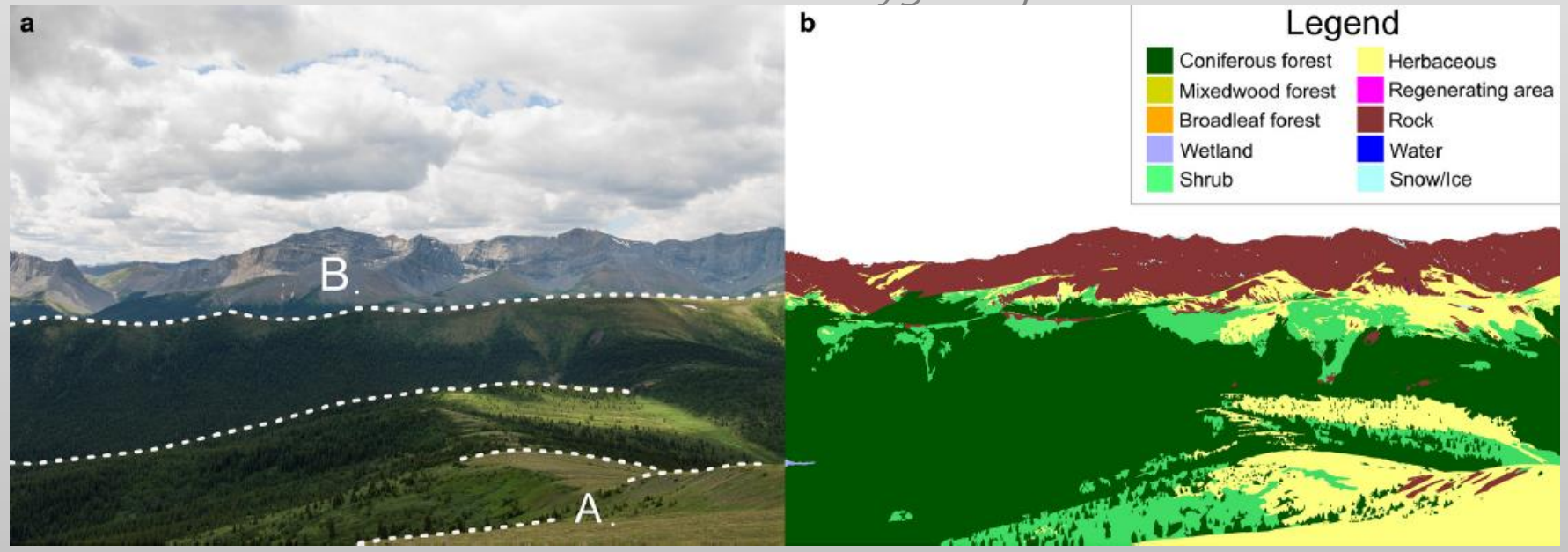
Most frequent: categorical data (land cover type)

Mean: continuous data (elevation, temp, precipitation)

Conversion Between Data Models

- **Rasterization** (convert Vector to Raster): **Polygon to Raster**
  - Why we might want to do this?
    1. because doing geometry calculations on vector data is slow over big areas
    2. because we often want to compute changes from one attribute to another

Polygon representation of land cover



Source: Fortin et al., 2018

Conversion Between Data Models

- **Rasterization** (convert Vector to Raster): **Polygon to Raster**
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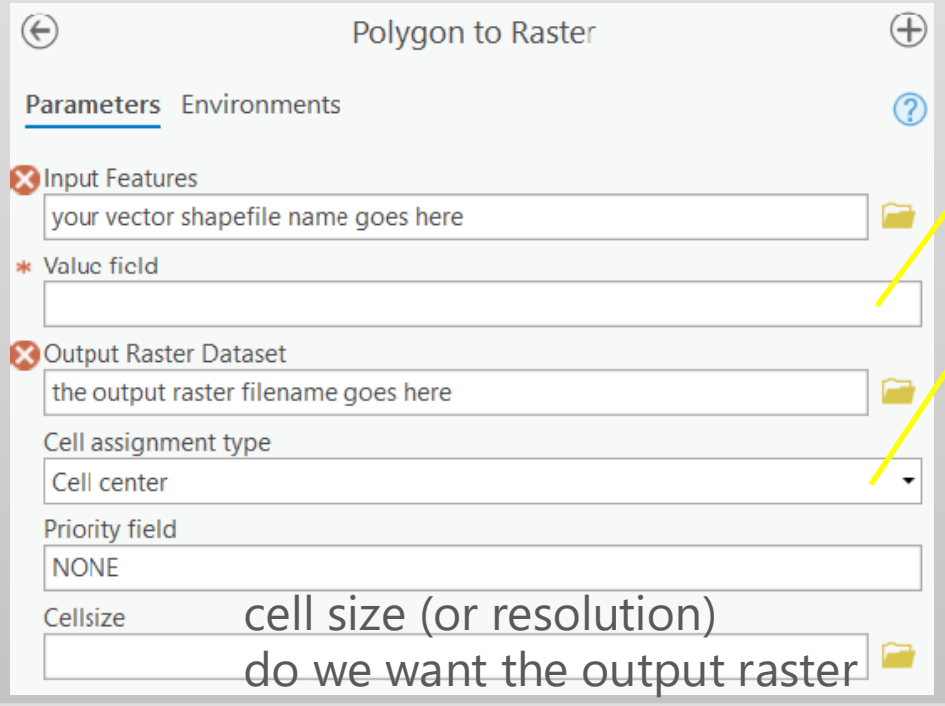


cell size (or resolution)
do we want the output raster

The attribute field of the input polygon that you want your raster to represent

Cell assignment method. What happens if there's more than one polygon in the resulting raster cell?!

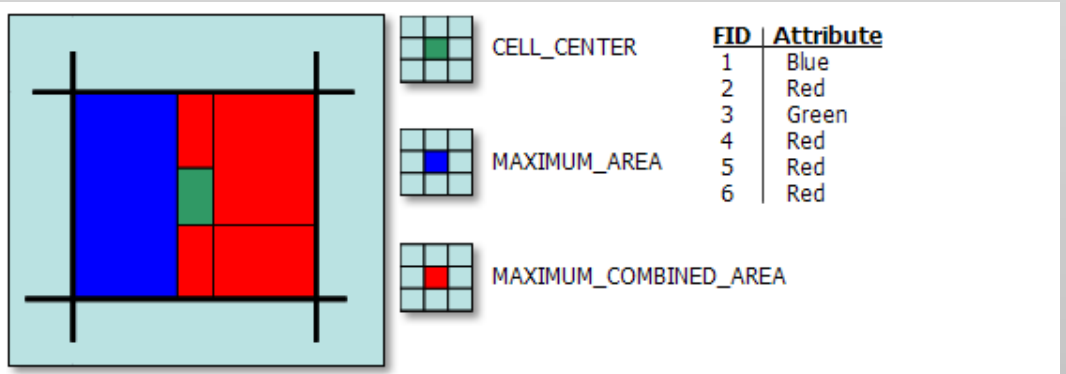


Illustration of six polygons that fall within a single cell

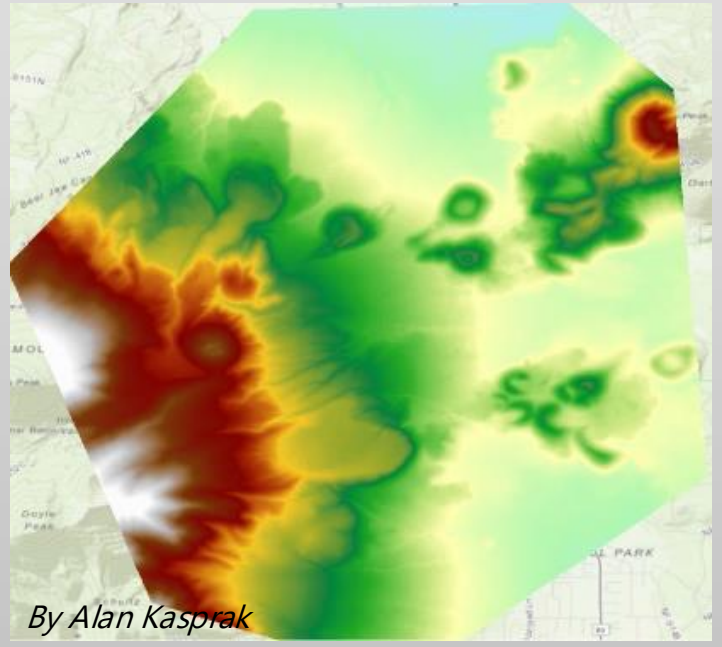
https://pro.arcgis.com/en/pro-app/latest/tool-reference/conversion/polygon-to-raster

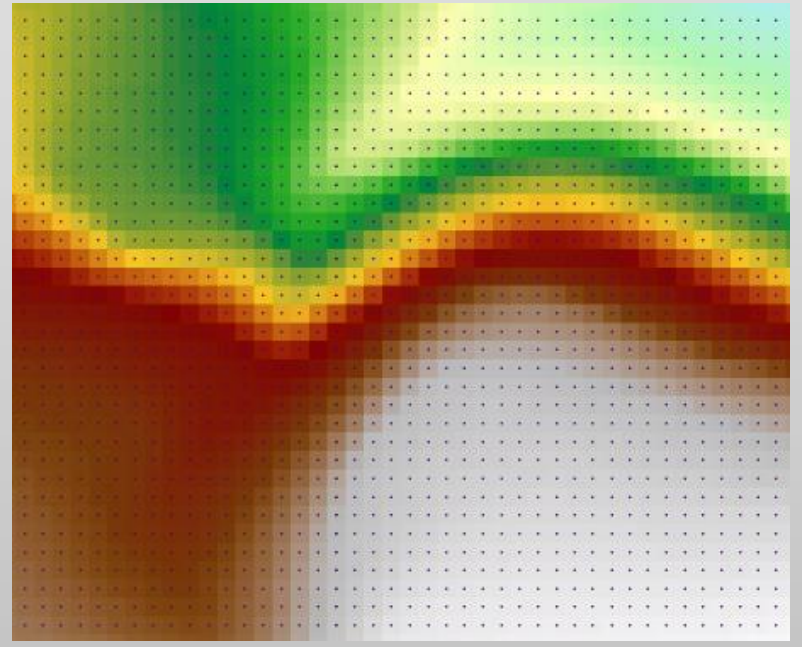
Conversion Between Data Models

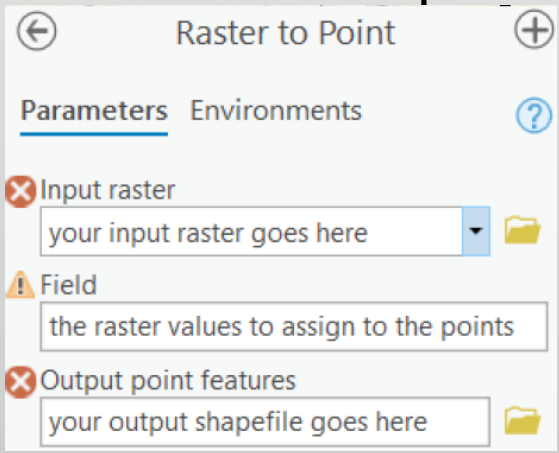
- **Vectorization** (convert Raster to Vector)

Conversion Between Data Models

- **Vectorization** (convert Raster to Vector): **Raster to Point**
  - Use:
    - For displaying values differently
    - Further post-processing of point data: e.g. elevation data convert to point



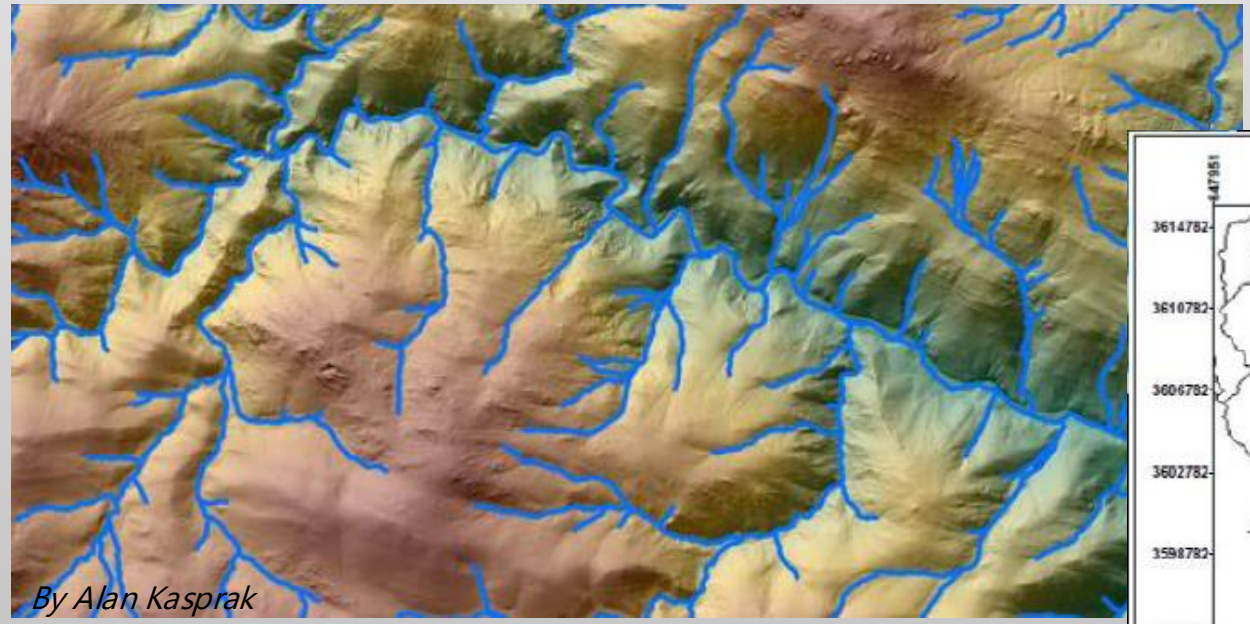




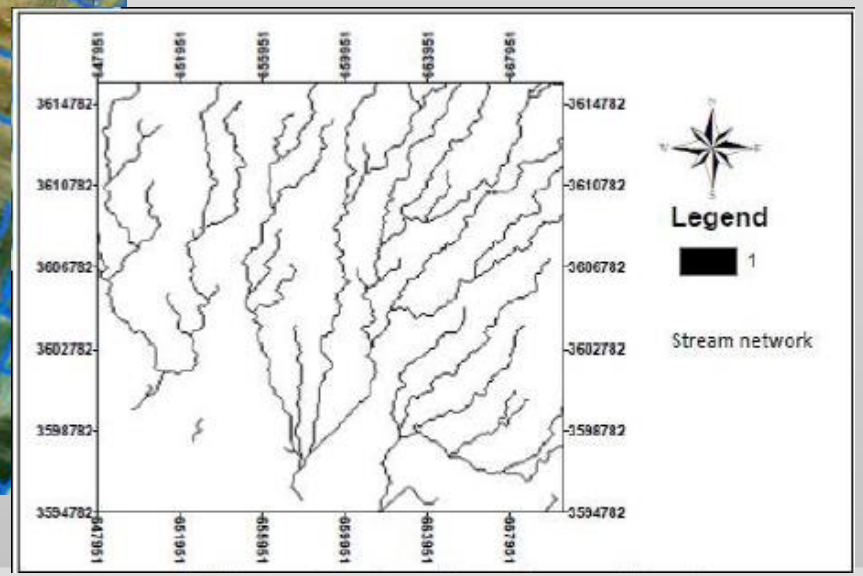
Raster to Point *conversion tool in ArcPro will get you there but it can be really slow on big rasters.*

Conversion Between Data Models

- **Vectorization** (convert Raster to Vector): **Raster to Polyline**
  - Use:
    - Often used in hydrologic modeling
    - Used in image classification (how can we compute the length of roads)



Things that are inherently linear (e.g., streams, road)



Conversion Between Data Models

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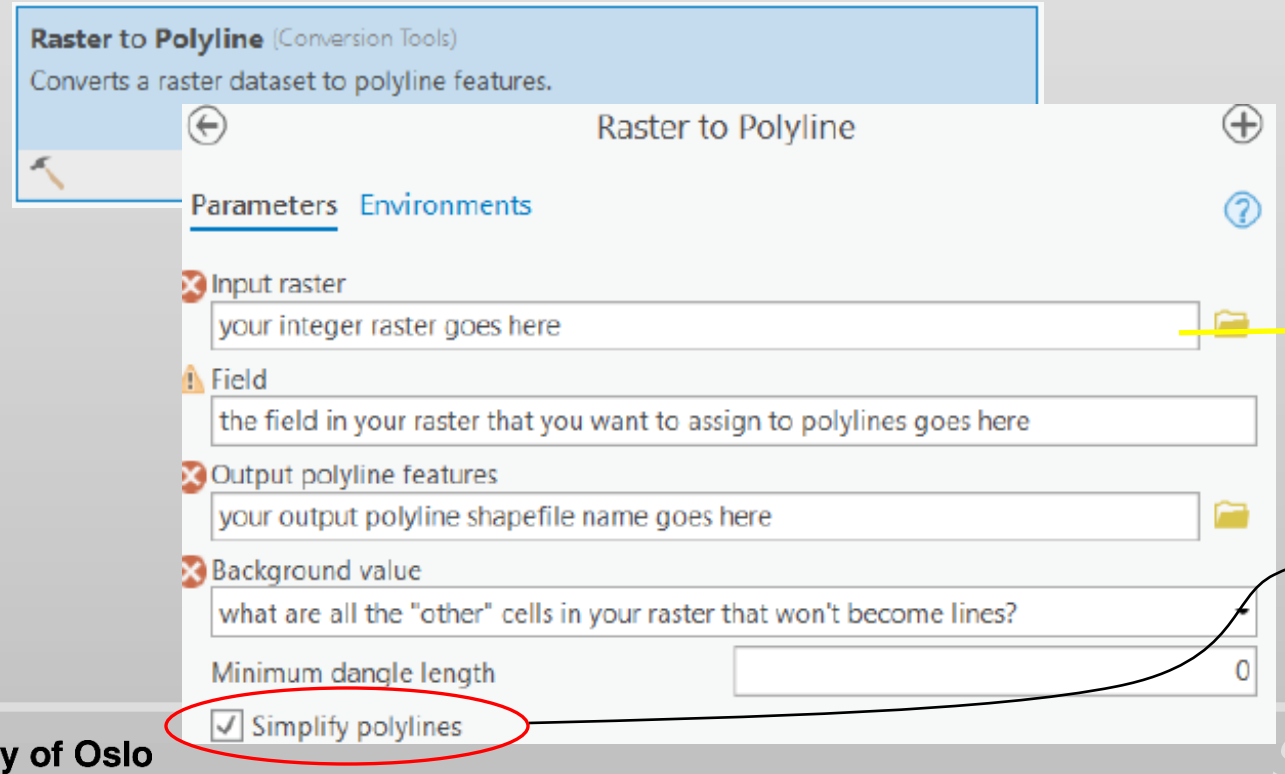
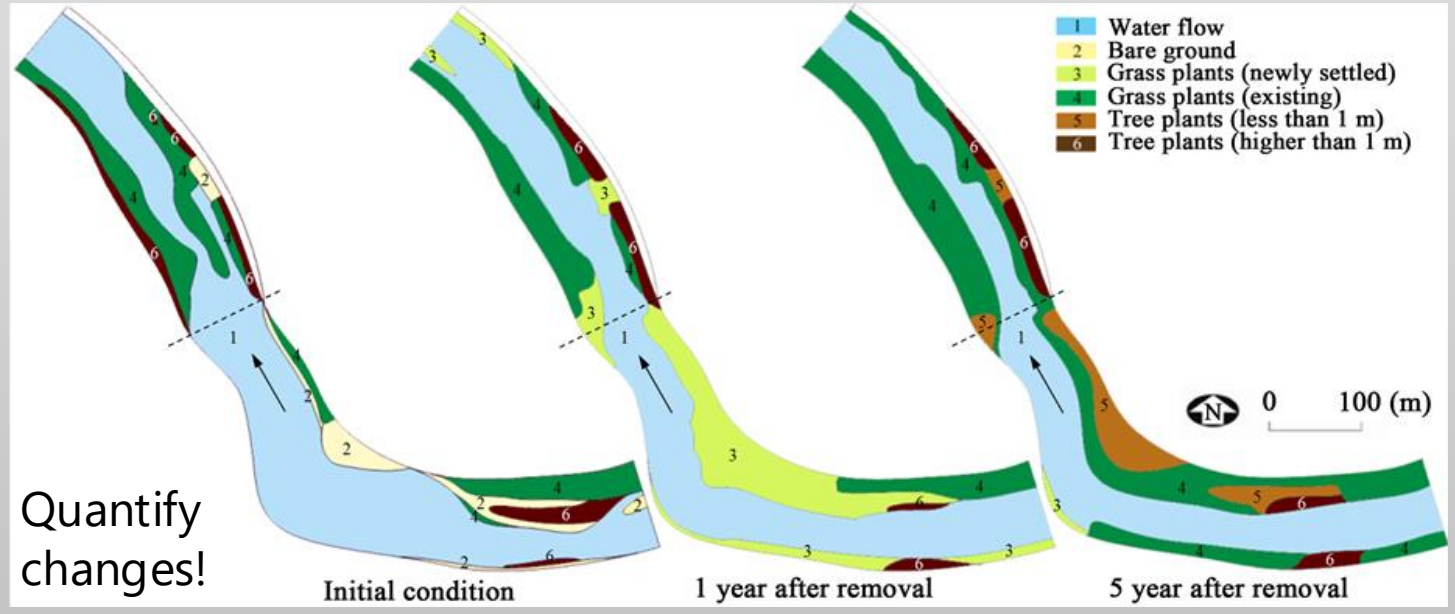


Note: Input raster needs to be an "integer" type

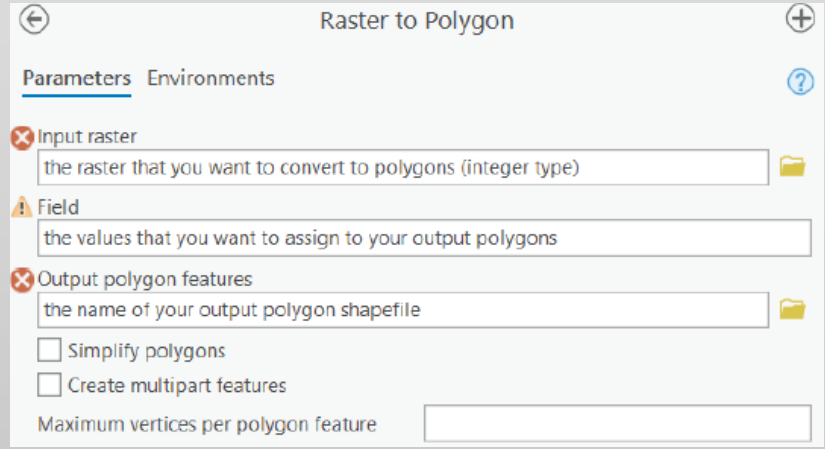
The polylines are smoothed and do not follow the square edge of the raster

Conversion Between Data Models

- **Vectorization** (convert Raster to Vector): **Raster to Polygon**
  - Use:
    - Nicely displaying features on a map *(remember raster are pixel!)*
    - Computing the distance between features
    - Computing the area of groups of features (e.g., different types of forest)



Quantify changes!



Example: Effects of a Low-Head Dam Removal on River Morphology and Riparian Vegetation. Kim et al., 2014

Conversion Between Data Models

Raster to Raster Conversion

- To change formats and cell sizes/resolutions…

  Why?

  Example: you have two rasters
  - One at high resolution
  - Another one at low resolution

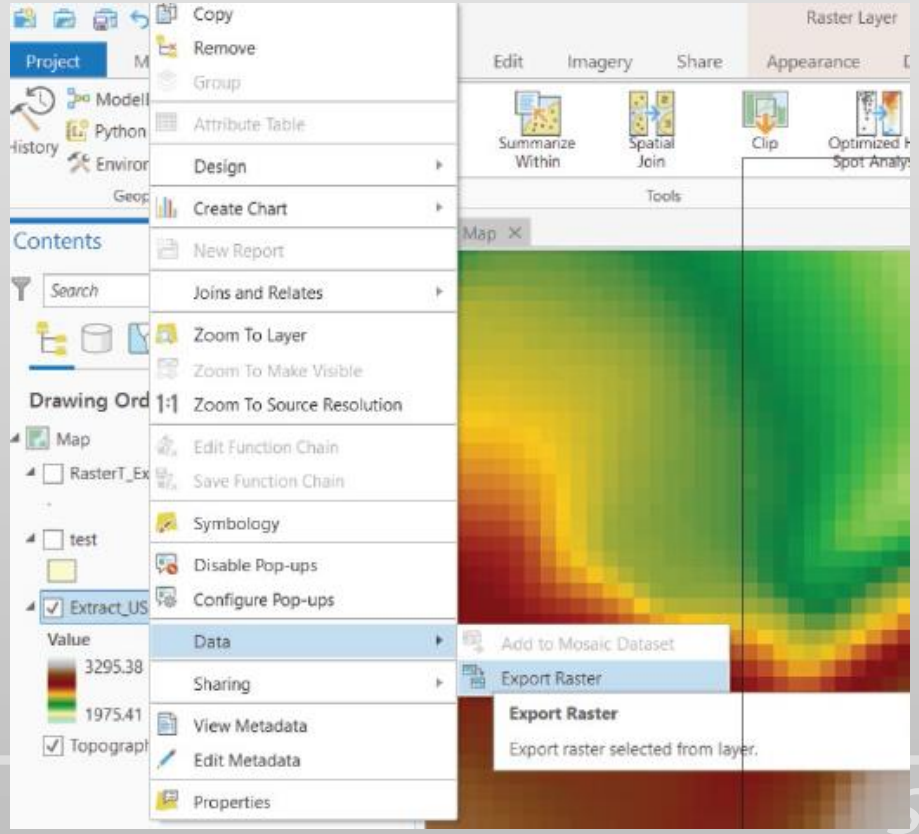
  For comparison and more accurate analysis the two rasters should have the same resolution:
  → resample the finer resolution raster to the same resolution of the coarser ones

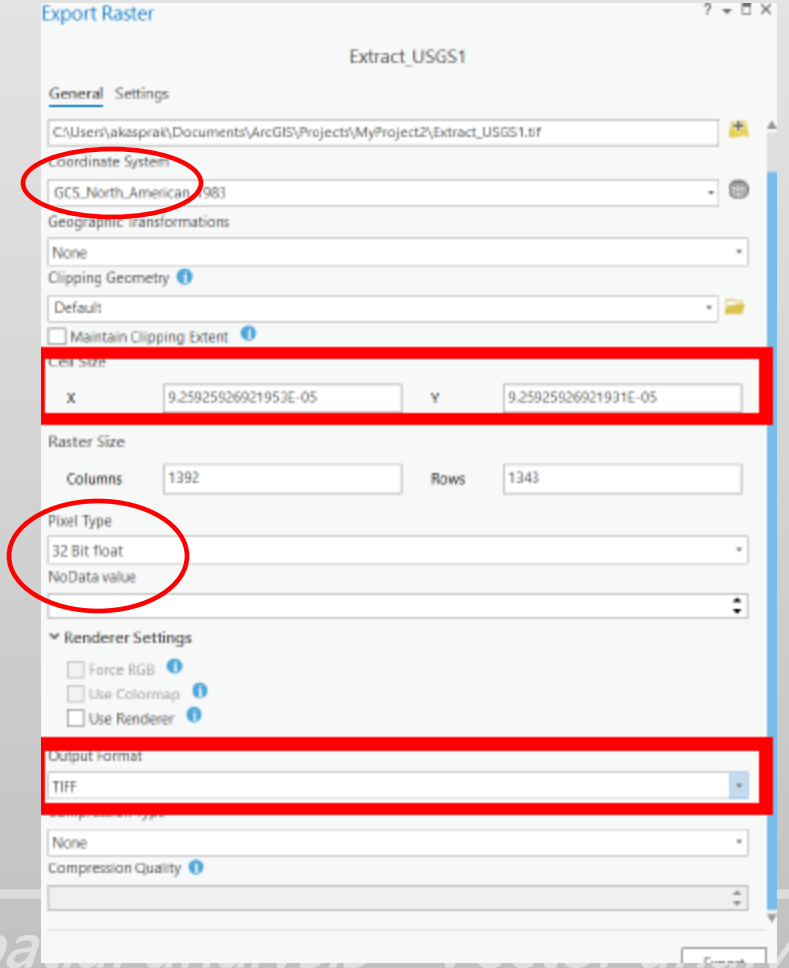
Conversion Between Data Models

Raster to Raster Conversion

- To change formats and cell sizes/resolutions…
  - Tool *Export raster* (the quickest way)

Making all the raster datasets the same resolution

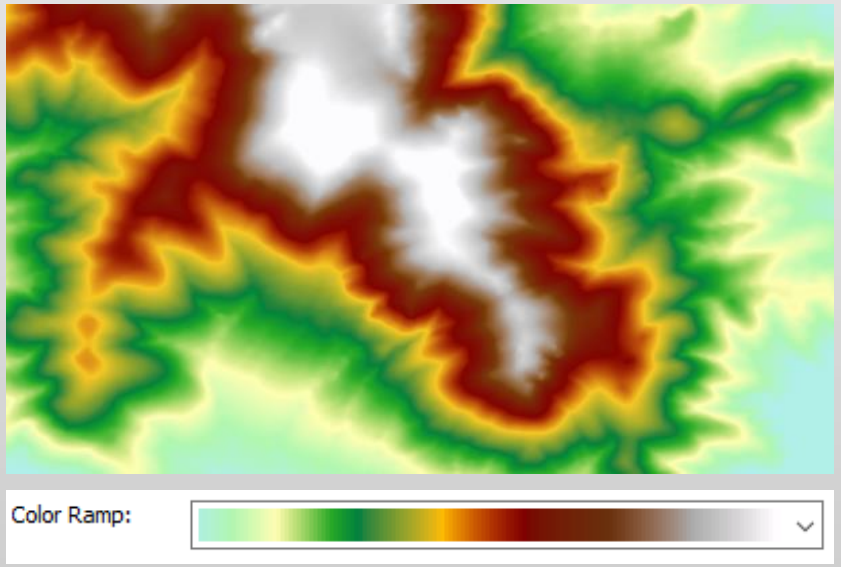




Conversion Between Data Models

Raster to Raster Conversion

- To change cell sizes/resolutions: Tool *Resample*



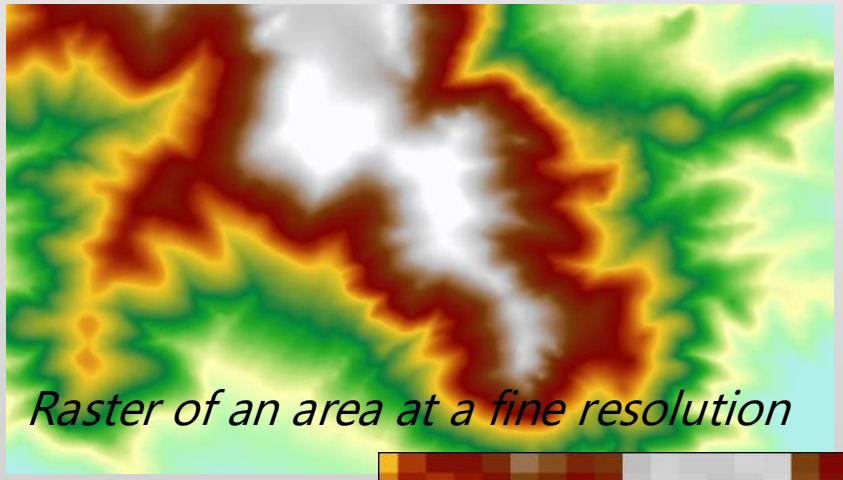
From 10 m resolution…

What do you see here?

Conversion Between Data Models

Raster to Raster Conversion

- To change cell sizes/resolutions: Tool *Resample*

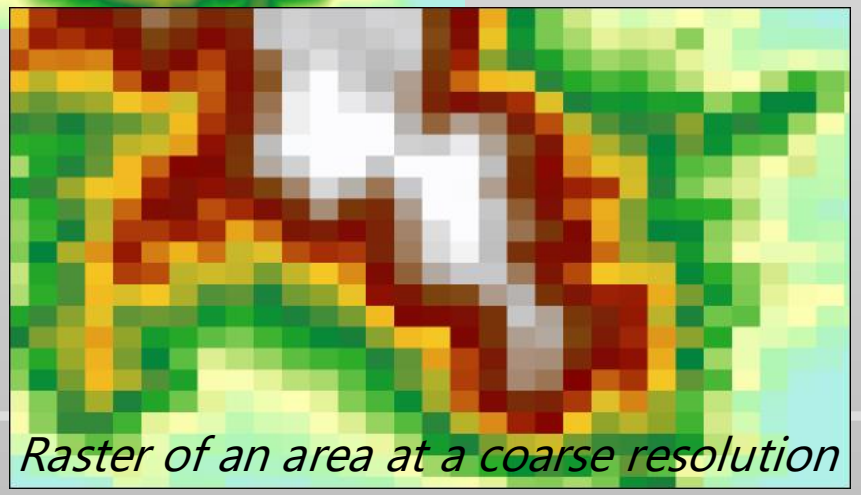


Raster of an area at a fine resolution

From 10 m resolution…

What happened when I altering the resolution of the raster?

…to 200 m resolution

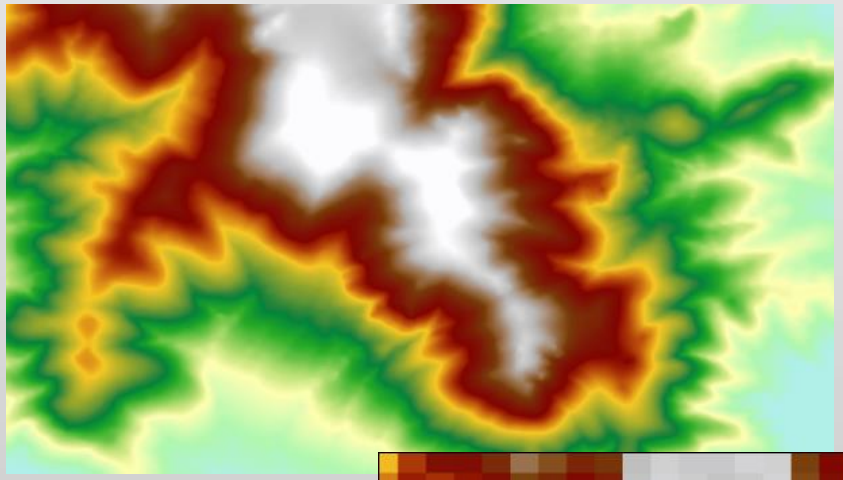


Raster of an area at a coarse resolution

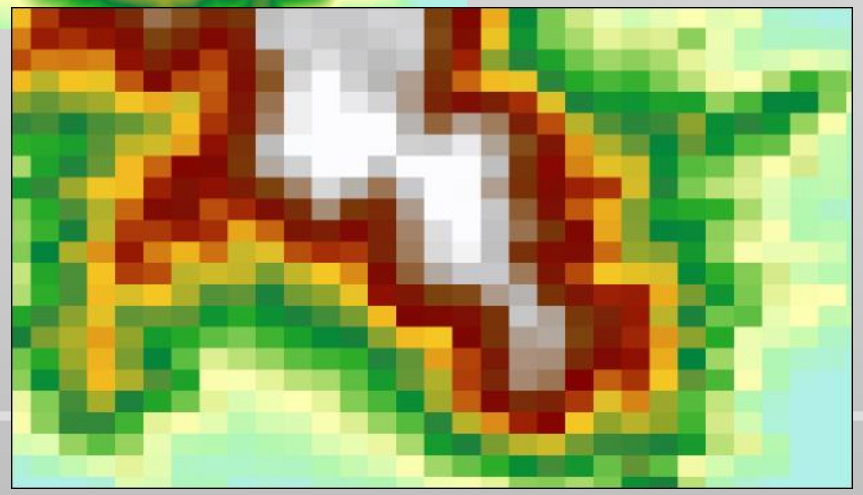
Conversion Between Data Models

Raster to Raster Conversion

- To change cell sizes/resolutions: Tool *Resample*



From 10 m resolution…



…to 200 m resolution

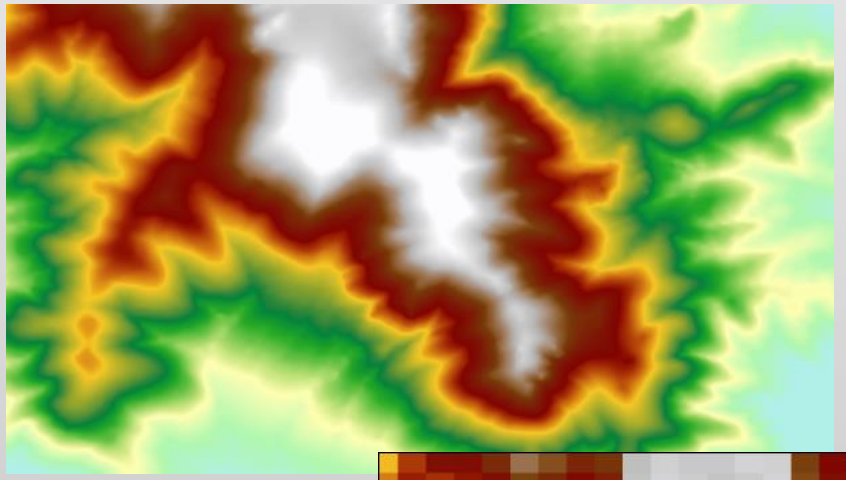
<u>Different choices for resampling the raster:</u>

1. Nearest Neighbor → best for discrete data
2. Bilinear → best continuous data (elevation, slope, temperature, precip.)
3. Cubic Convolution
4. Majority

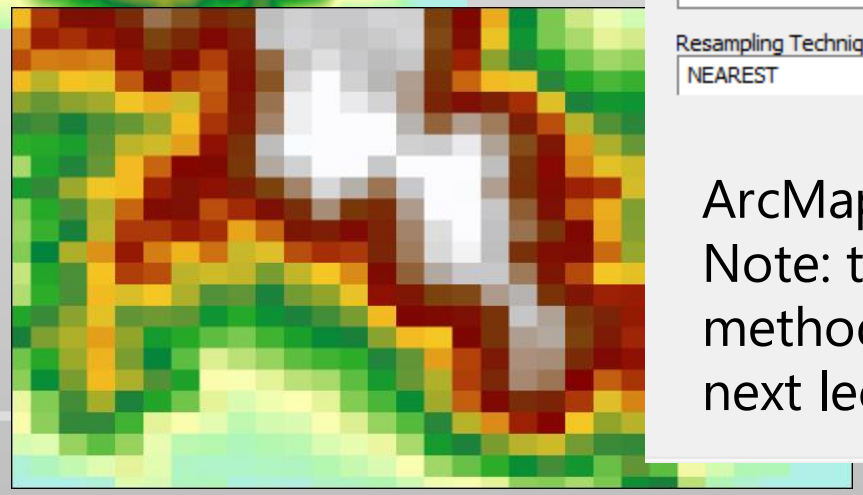
Conversion Between Data Models

Raster to Raster Conversion

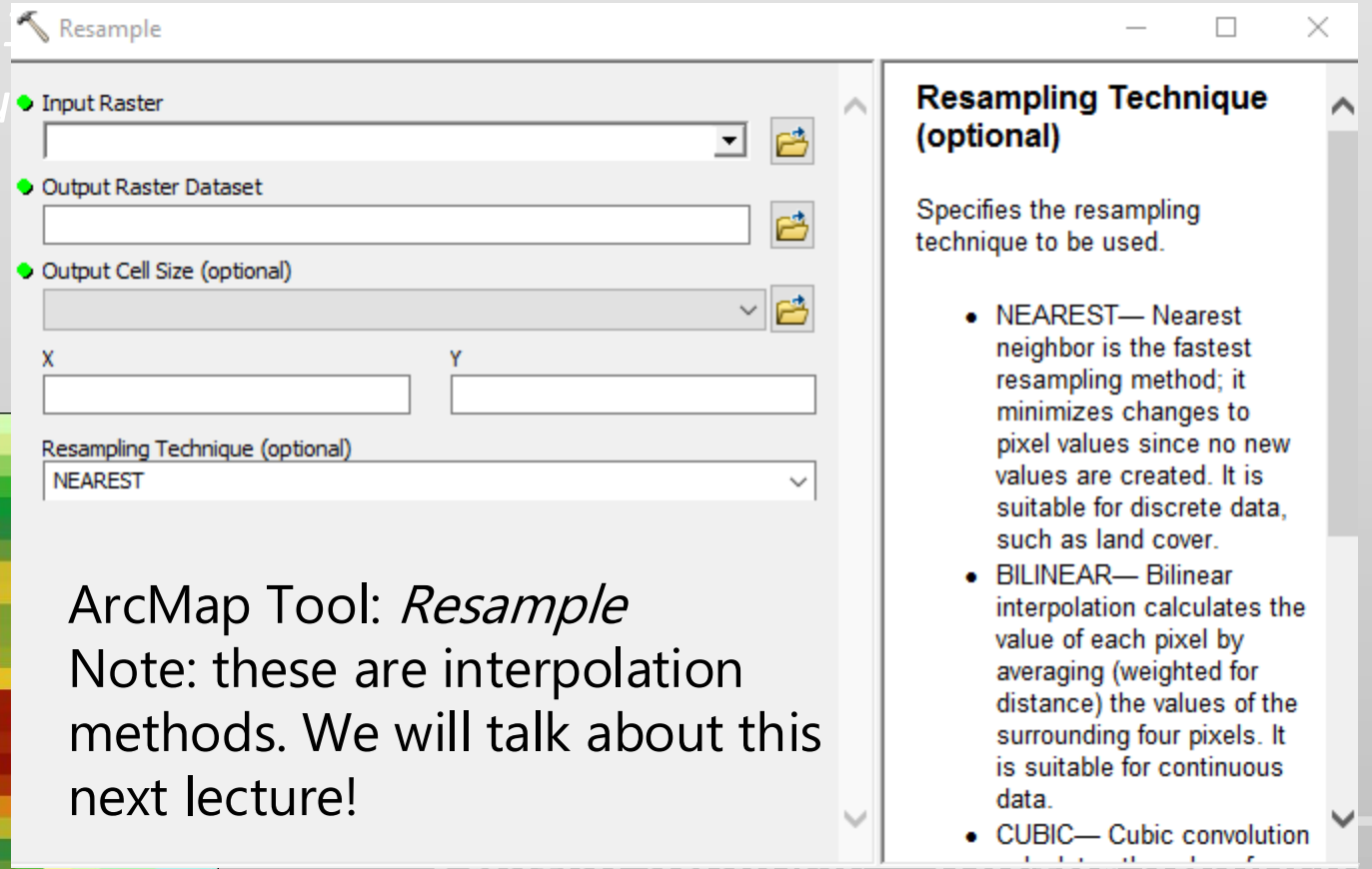
- To change cell sizes/resolutions: Tool *Resample*



From … resolu



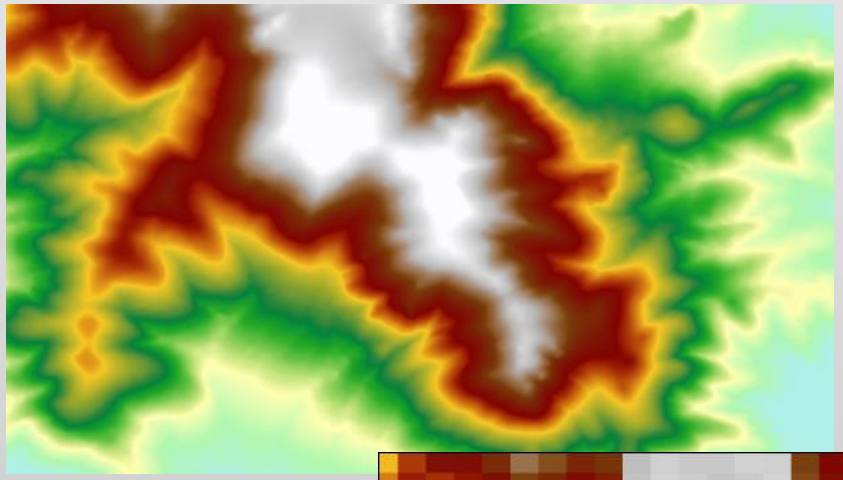
…to 200 m resolution



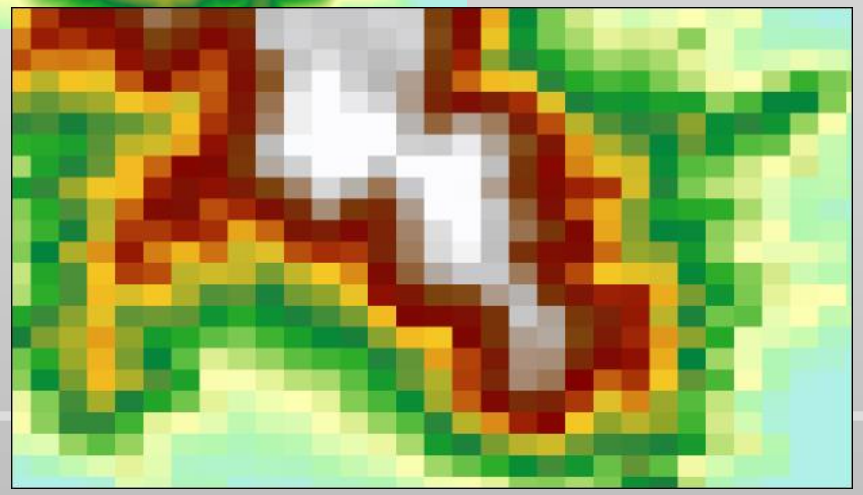
ArcMap Tool: *Resample*
Note: these are interpolation methods. We will talk about this next lecture!

Conversion Between Data Models

- **Raster to Raster Conversion**
  - To change cell sizes/resolutions



From 10 m resolution…



…to 200 m resolution

Can I convert elevation raster to polygon?

Learning Objectives

1

Conversion between data models

- Rasterization
- Vectorization

2

Geometric operation (vector)

- Distance
- Buffer
- …

3

Attribute operations (vector & raster)

- Selection by attribute and location
- Aggregation
- Overlay

Today's topics

Vector analysis: question?

- Where is object A located? → coordinates
- How are points and lines distributed in the space?
- Where is object A in relation to another object B? → overlay, distance
- How many A-objects are there near object B? → distance buffer
- How many A-objects are there within an area determined by object B? → overlay, aggregation / sum
- What is the shortest / fastest way between A and B? → network

What analysis that can be carried out depends on:
measurement level, data type and data structure, and software

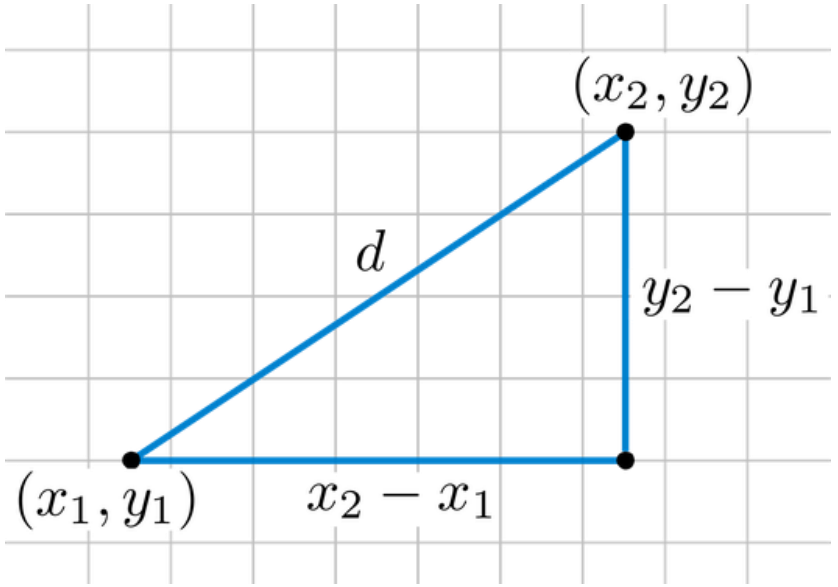
Types of analysis / basic operations

- Geometric operations
  - Distance
  - Buffers
  - Perimeter
  - Area
  - …

Geometric operations: Dimension

- Distance
  - Euclidean Distance *(most common distance)*
  - Manhattan distance
  - Network distance (e.g. road, river length)
  - Surface distance (3D distance)
  - Cost distance

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$



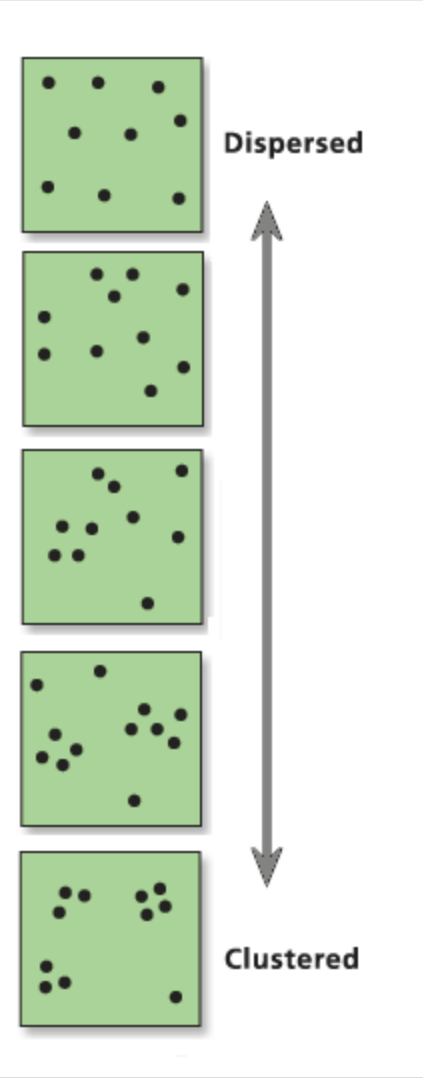
The Euclidean distance between two points in either the plane or 3D space measures the length of a segment connecting the two points

Geometric operations: Dimension

- Distance
  - Euclidean Distance *(most common distance)*
  - Manhattan distance
  - Network distance (e.g. road, river length)
  - Surface distance (3D distance)
  - Cost distance

When do you use the Euclidean distance?

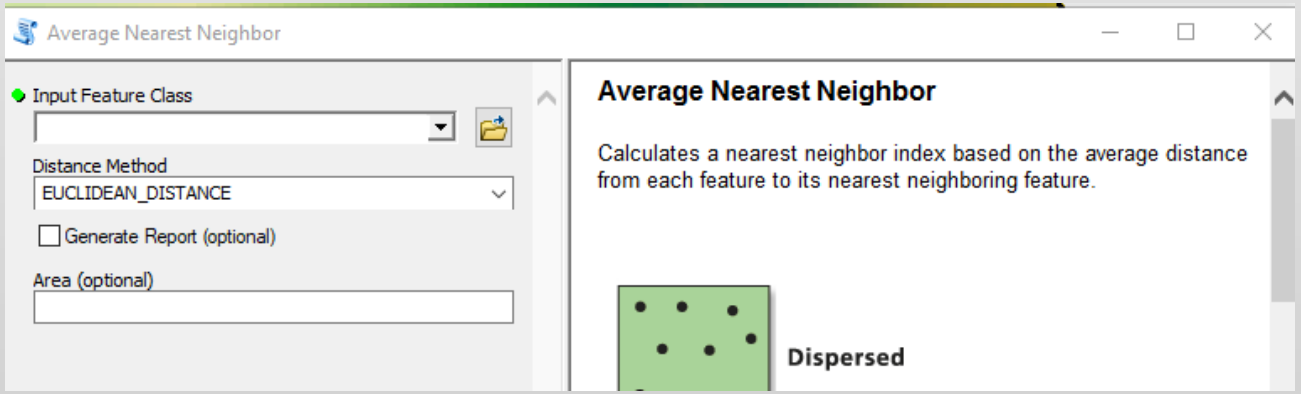
Example:
Understand the distribution of you data: dispersed or clustered?



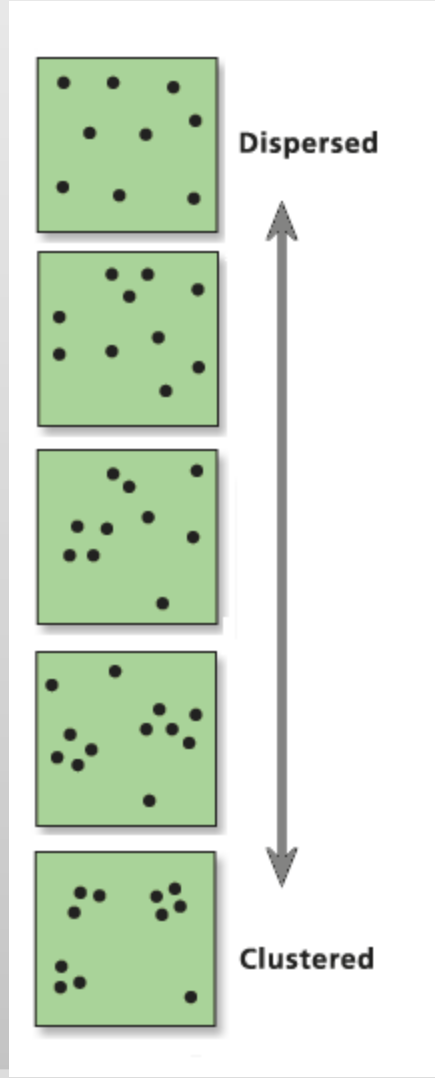
Geometric operations: Dimension

- Distance
  - Euclidean Distance *(most common distance)*

    Tool: *Average Nearest Neighbor*

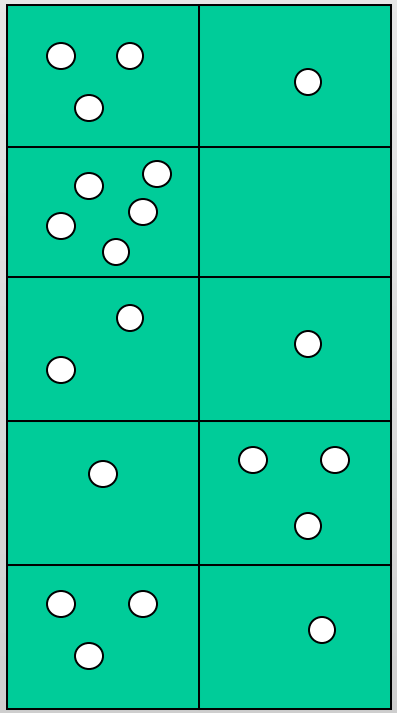


The Average Nearest Neighbor tool measures the distance between each feature centroid and its nearest neighbor's centroid location. It then averages all these nearest neighbor distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analyzed is considered clustered.



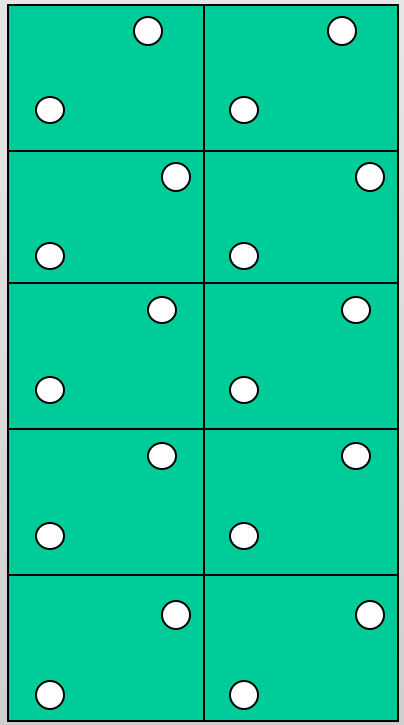
Geometric operations: Data distributions

How data (points) are distributed?



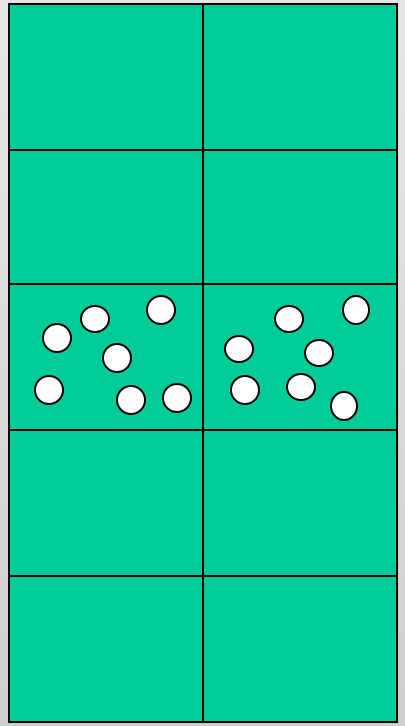
RANDOM

Any point is equally likely to occur at any location, and the position of any point is not affected by the position of any other point



UNIFORM/DISPERSED

Every point is as far from all of its neighbors as possible: "unlikely to be close"



CLUSTERED

Many points are concentrated close together, and there are large areas that contain very few, if any, points: "unlikely to be distant"

Geometric operations: Average nearest neigh. (NN) index

How do I know how my data is distributed?

Index: **NN Index:** The Nearest Neighbor Index (Uncorrected)

$$NNI = \frac{\bar{d}}{E(\bar{d})}$$

where: **Avg. Dist.:** Average Nearest Neighbor Distance

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n}$$

Exp. Avg.: Expected Average Nearest Neighbor Distance (Uncorrected)

$$E(\bar{d}) = 0.5\sqrt{\frac{A}{n}}$$

Briggs UT-Dallas GISC 6382 Spring 2004

Interpretation of the index (average nearest neighbor ratio)

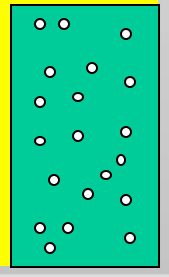
- the index is **less than 1** → the pattern exhibits **clustering**
- the index is **greater than 1** → the trend is toward **dispersion**

Geometric operations: NN index

RANDOM

Point	Nearest Neighbor	Distance
1	2	1
2	3	0.1
3	2	0.1
4	5	1
5	4	1
6	5	2
7	6	2.7
8	10	1
9	10	1
10	9	1
		10.9

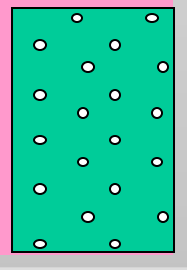
Mean distance	1.09
Area of Region	50
Density	0.2
Expected Mean	1.118034
NNI	0.974926



UNIFORM

Point	Nearest Neighbor	Distance
1	3	2.2
2	4	2.2
3	4	2.2
4	5	2.2
5	7	2.2
6	7	2.2
7	8	2.2
8	9	2.2
9	10	2.2
10	9	2.2
		22

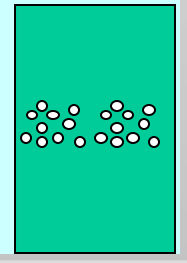
Mean distance	2.2
Area of Region	50
Density	0.2
Expected Mean	1.118034
NNI	1.96774



CLUSTERED

Point	Nearest Neighbor	Distance
1	2	0.1
2	3	0.1
3	2	0.1
4	5	0.1
5	4	0.1
6	5	0.1
7	6	0.1
8	9	0.1
9	10	0.1
10	9	0.1
		1

Mean distance	0.1
Area of Region	50
Density	0.2
Expected Mean	1.118034
NNI	0.089443

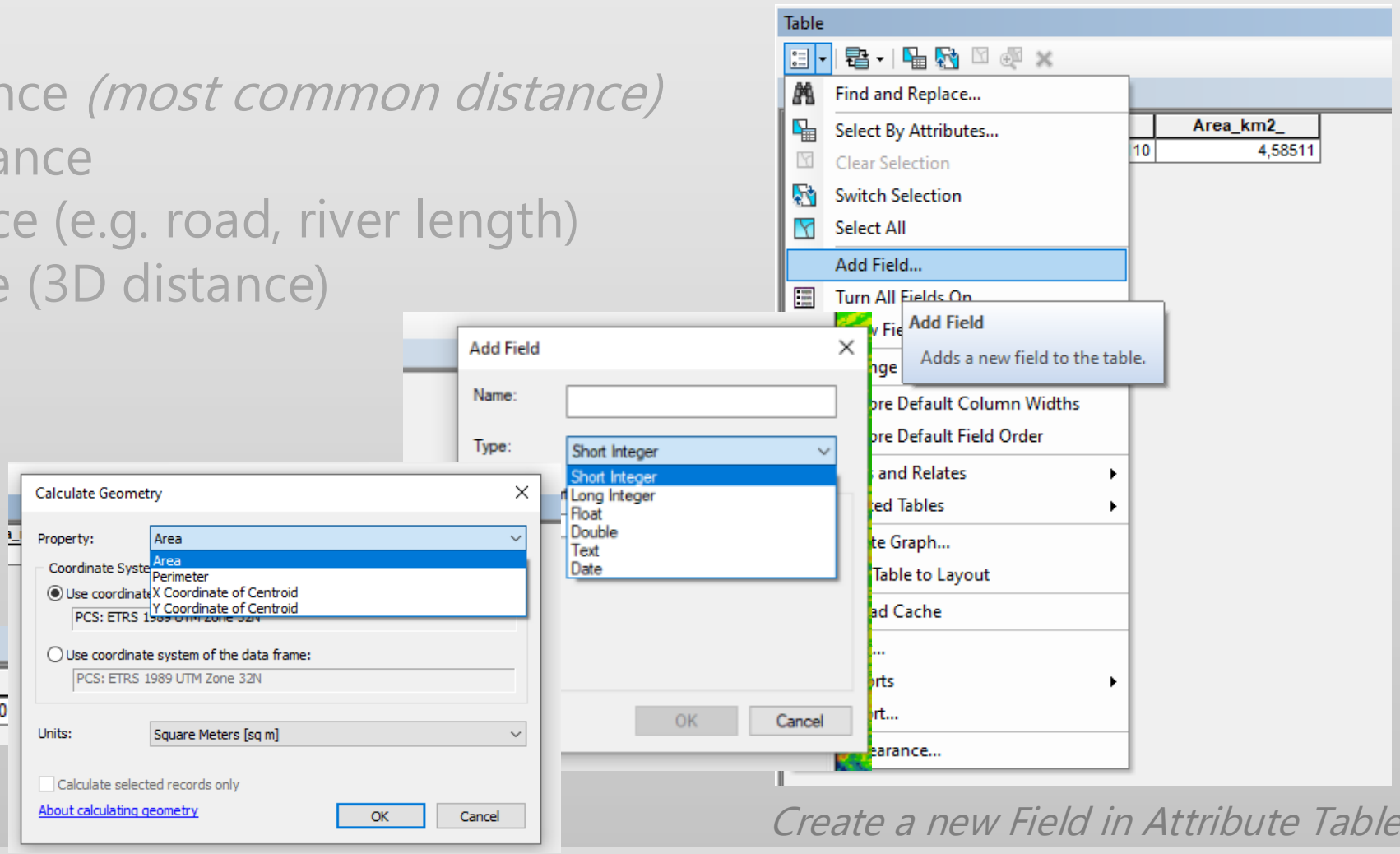


Geometric operations: Dimension

- Distance
  - Euclidean Distance *(most common distance)*
  - Manhattan distance
  - Network distance (e.g. road, river length)
  - Surface distance (3D distance)
  - Cost distance
- Area
  - Surface area
  - Perimeter

AOI_GepatchALL_v2

FID	Shape *	Id	Area_m2_
0	Polygon	0	4585110



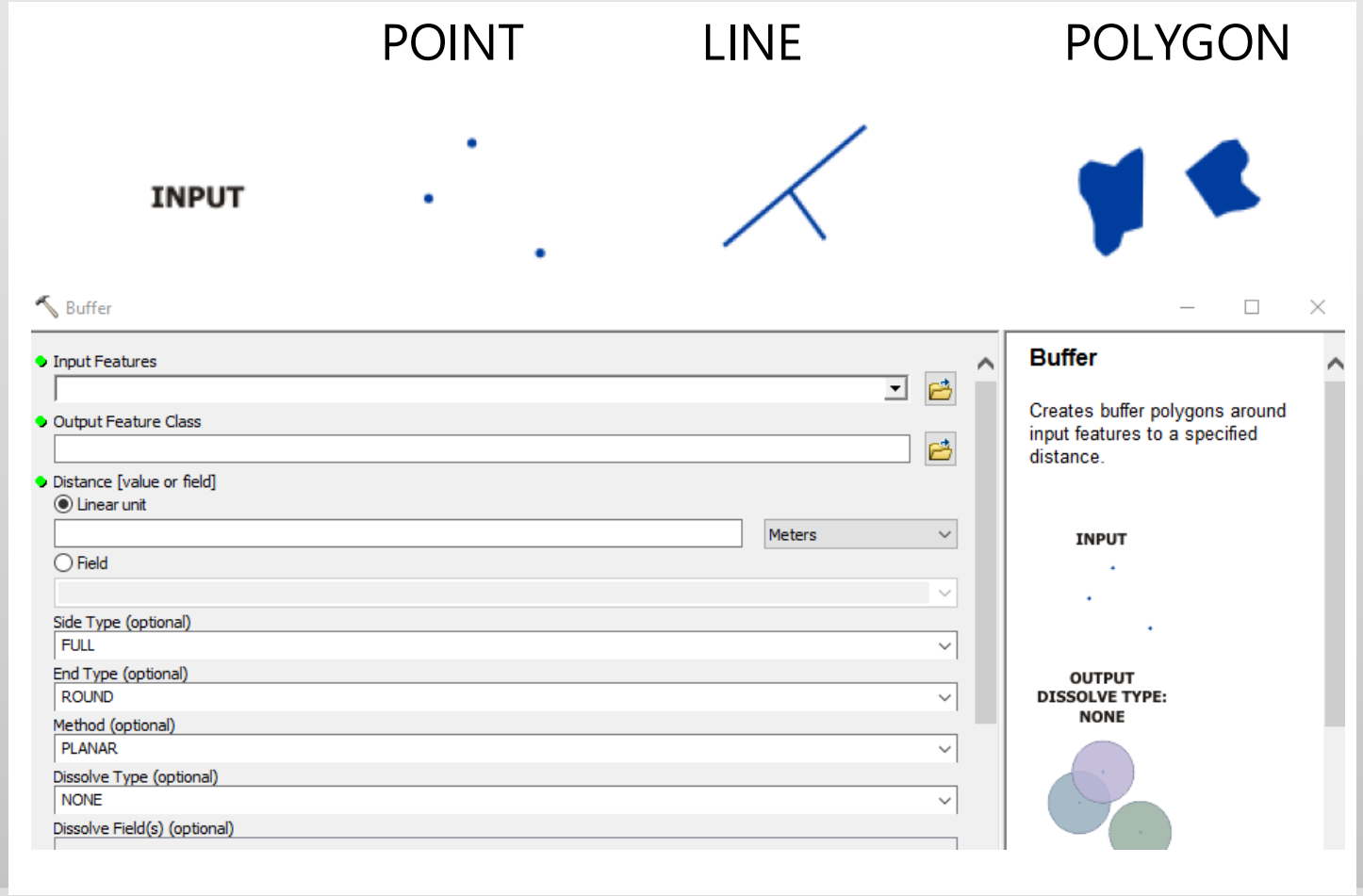
Create a new Field in Attribute Table

Geometric operations: Buffer

- Single, Multiple ring buffers

Creates buffer polygons around input features to a specified distance

Tool: *Buffer*

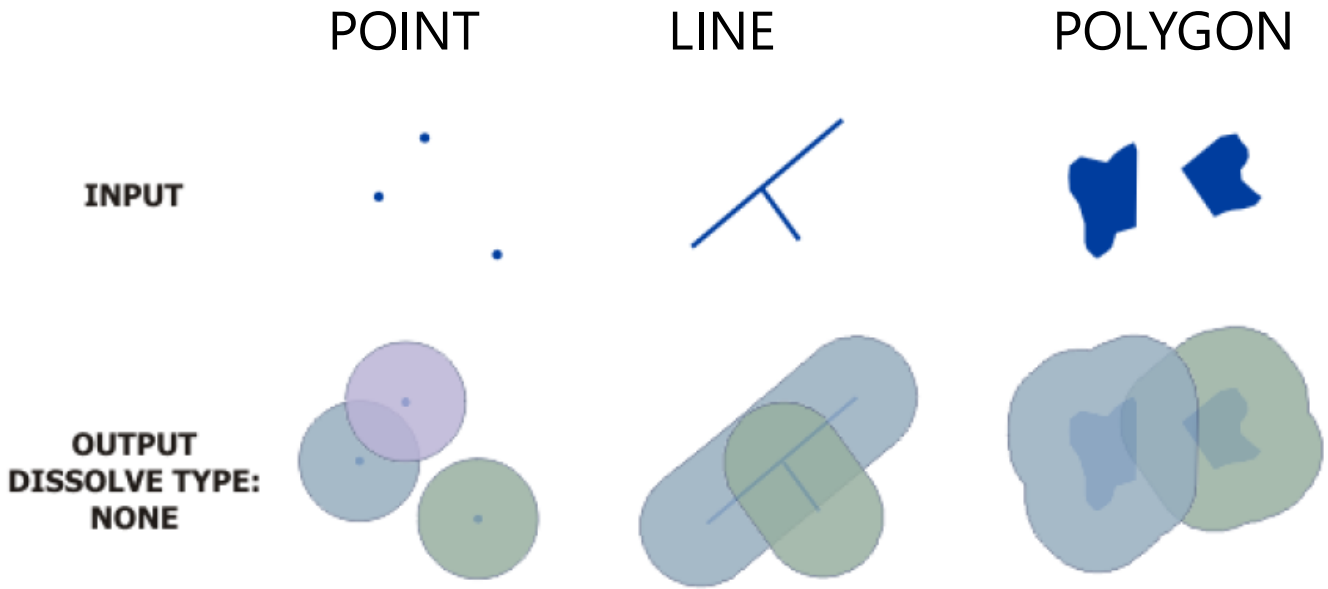


Geometric operations: Buffer

- Single, Multiple ring buffers

Creates buffer polygons around input features to a specified distance

– without “Dissolve”



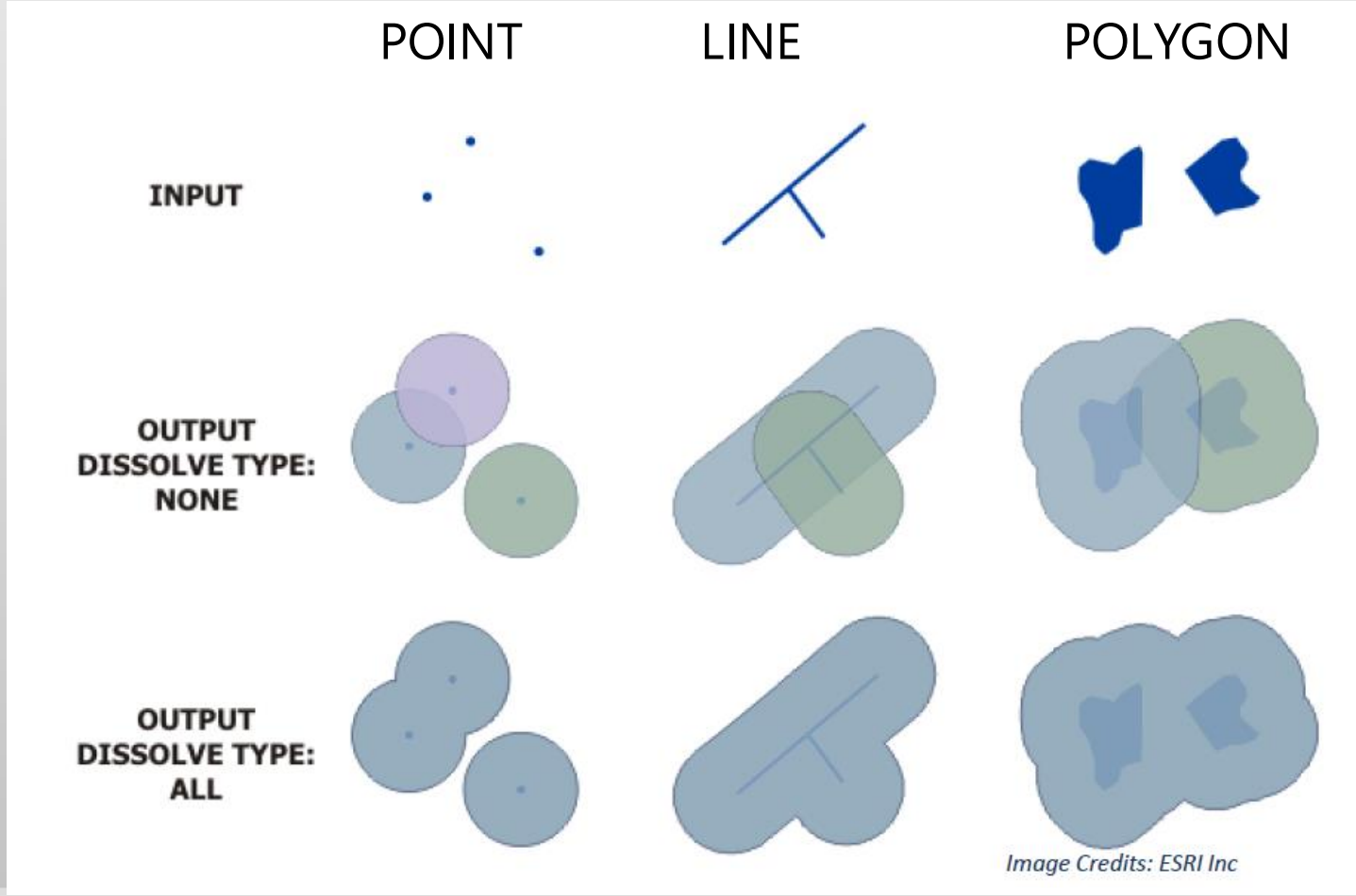
Buffers are rings drawn around features at a specified distance from the features

Geometric operations: Buffer

- Single, Multiple ring buffers

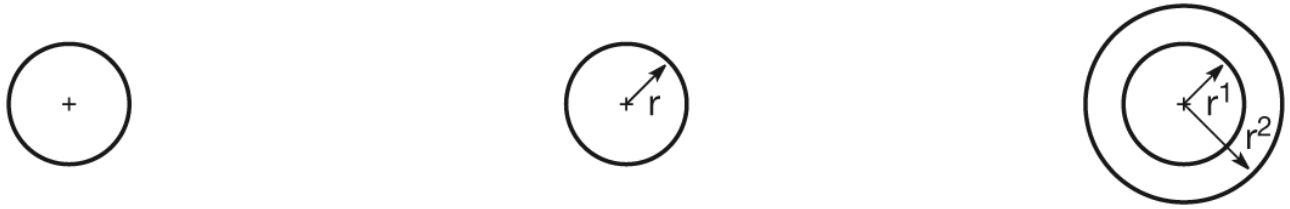
Creates buffer polygons around input features to a specified distance

- without "Dissolve"
- with "Dissolve"



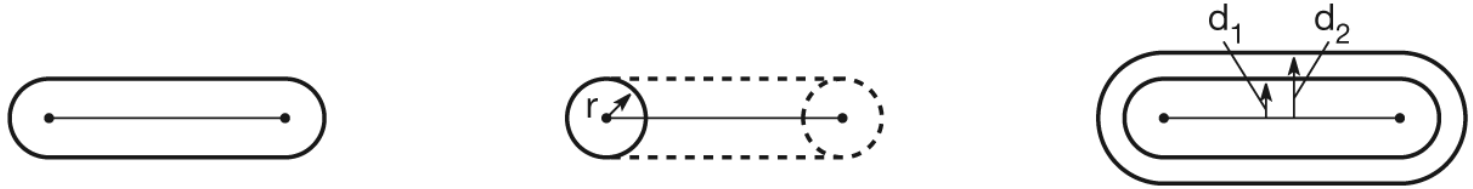
Geometric operations: Buffer

POINT



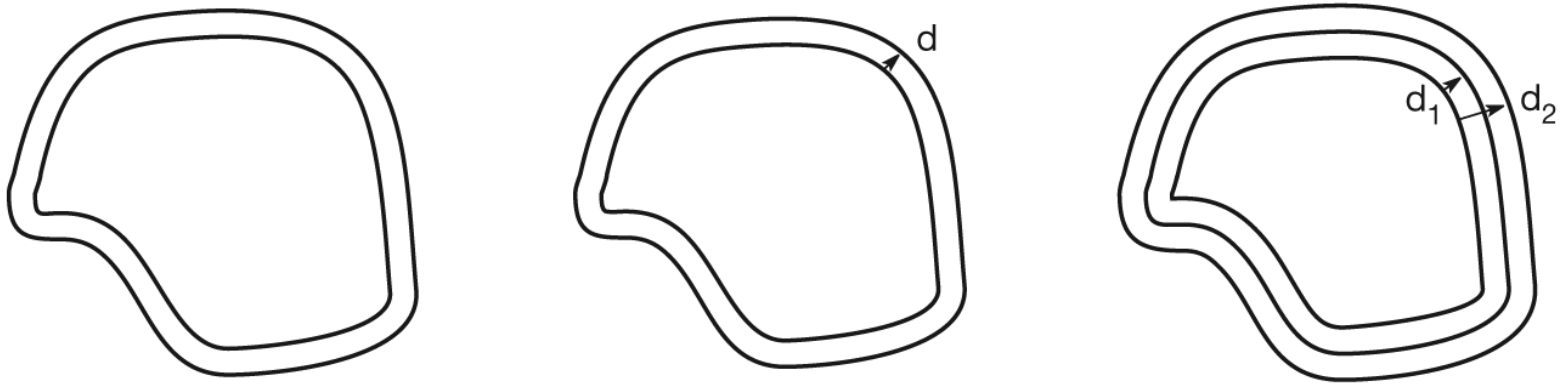
You define a buffer radius

LINE



You define a buffer distance

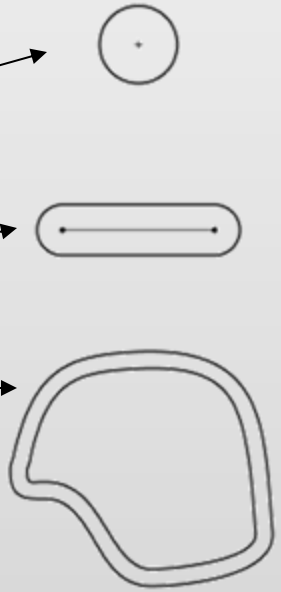
POLYGON



You define a buffer distance

Heywood *et al.*, An Introduction to Geographical Information Systems, 2/e

Geometric operations: Buffer



- Creates a zone (buffer) around an object:
  - Point buffer - a circle around the point
  - Line buffer - an elongated polygon around the line
  - Polygon buffer - a larger polygon around the polygon
- You can change your buffer distance i.e. the radius of the buffer zone from the object
  - Inner buffer: gives an internal buffer zone
- When we use it: Neighborhood analyses
  - What is within the buffers?
  - Spatial combination of attribute information based on location
  - Statistical operations (classification, regression, etc.)

Learning Objectives

1

Conversion between data models

- Rasterization
- Vectorization

2

Geometric operation (vector)

- Distance
- Buffer
- …

3

Attribute operations (vector & raster)

- Selection by attribute and location
- Aggregation
- Overlay

Today's topics

Types of analysis

- Attribute operations
  - Query / selection
    - based on attribute
    - based on location
  - Aggregation:
    - reclassification
    - removal of common boundaries
  - Overlay: union, clipping and intersect
  - Statistical operations (classification, regression, etc.)

Attribute operations: Queries, selection

An attribute query is the process of searching and retrieving records of features in a database based on desired attribute values

Do you know the SQL language (SQL = Standard Query Language)

Attribute operations: Queries, selection

- By Attribute values (Non-spatial query, SQL statement)
  - Single or multiple attribute questions (regardless of geography)
  - Data search and selection on the attribute Table
  - Boolean expression (and, or, not)
  - Statistical operations and function (sin, cos, sqrt, etc.)
  - Logical operators such as comparisons (>, <, =, >=, <=)

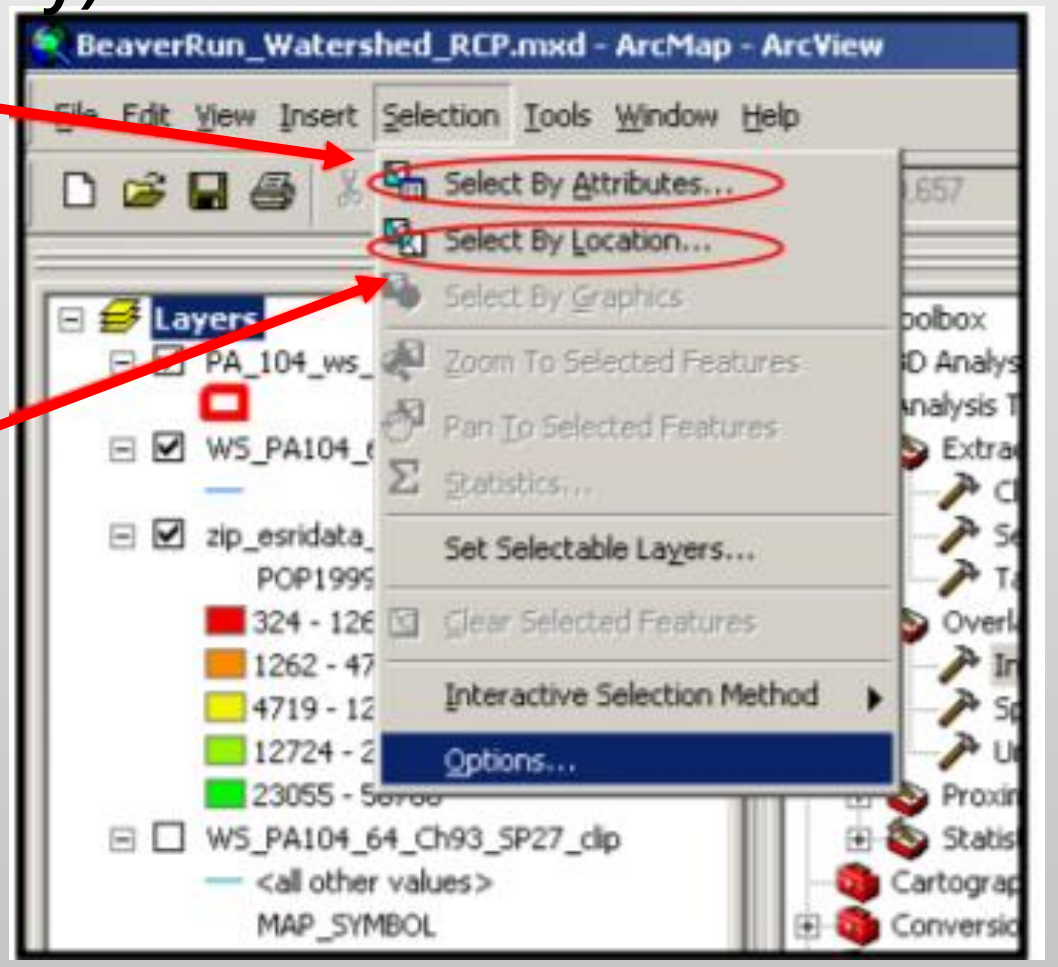
Attribute operations: Queries, selection

- By Attribute values (Non-spatial query, SQL statement)
  - Single or multiple attribute questions (regardless of geography)
  - Data search and selection on the attribute Table
  - Boolean expression (and, or, not)
  - Statistical operations and function (sin, cos, sqrt, etc.)
  - Logical operators such as comparisons (>, <, =, >=, <=)
- By Location (Spatial query or spatial selection)
  - Based on location information

Queries can be made interactively in GIS in single or multiple layers
- Query builder - Click Based
- Commands (e.g. SELECT, WHERE, AND, OR etc. ..)
- Map-based (e.g. click in the map to see attributes)

Attribute operations: Queries, selection

- By Attribute values (Non-spatial query)
- By Location (Spatial query)



Attribute operations: Queries, selection

- **By Attribute values (Non-spatial query)**

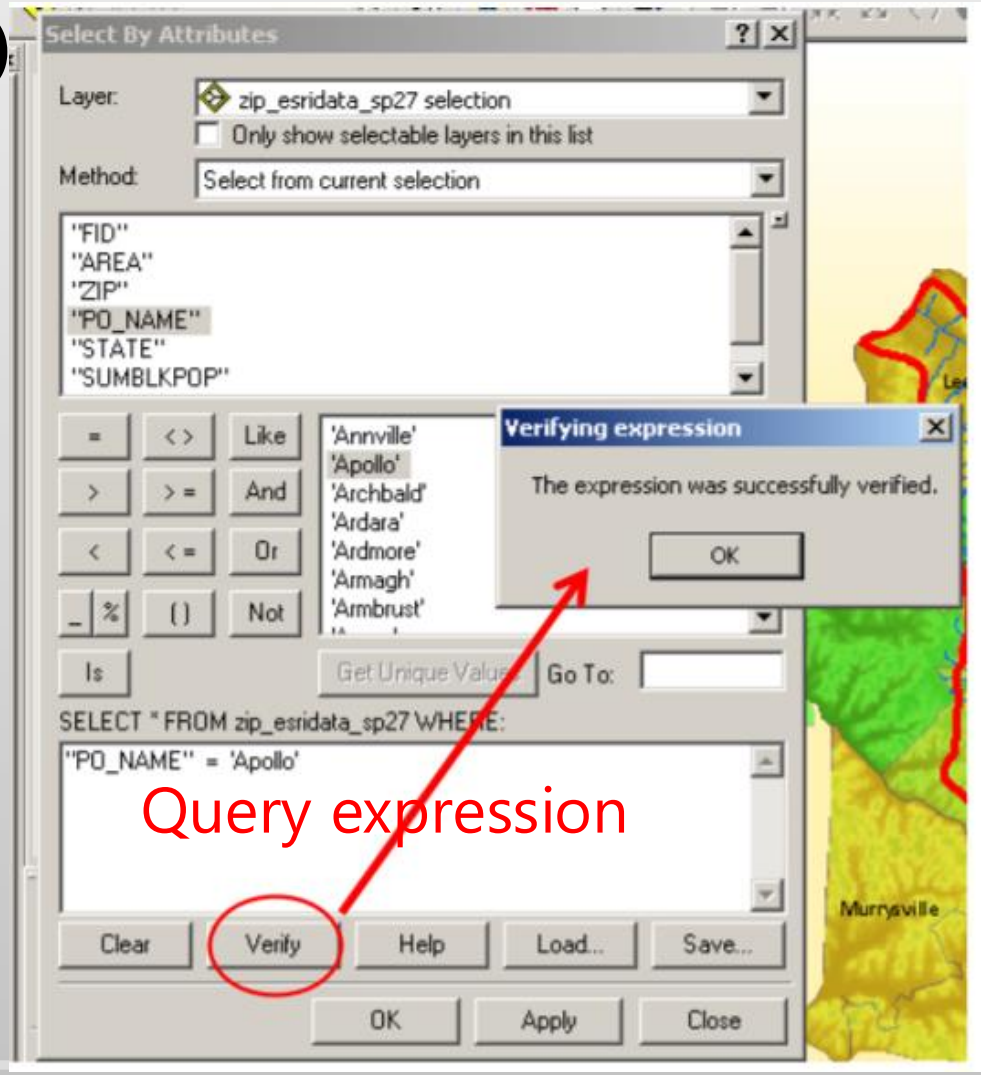
SQL = Standard Query Language

- Build the SQL statement by simply clicking and double-clicking

  "PO_NAME" = 'Apollo'

  logical operator

- Check your SQL statement with the "Verify " button
- Click "Apply"
- Click "OK"



Attribute operations: Queries, selection

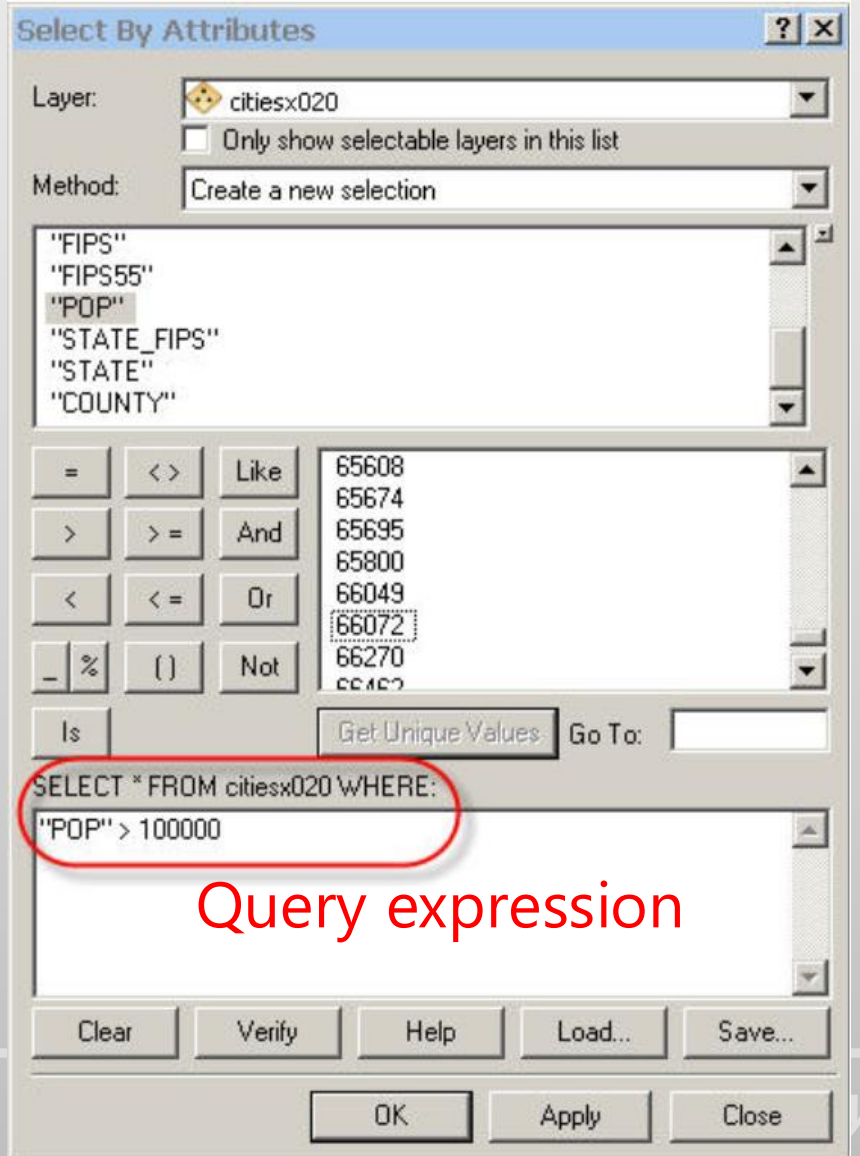
- **By Attribute values (Non-spatial query)**

SQL = Standard Query Language

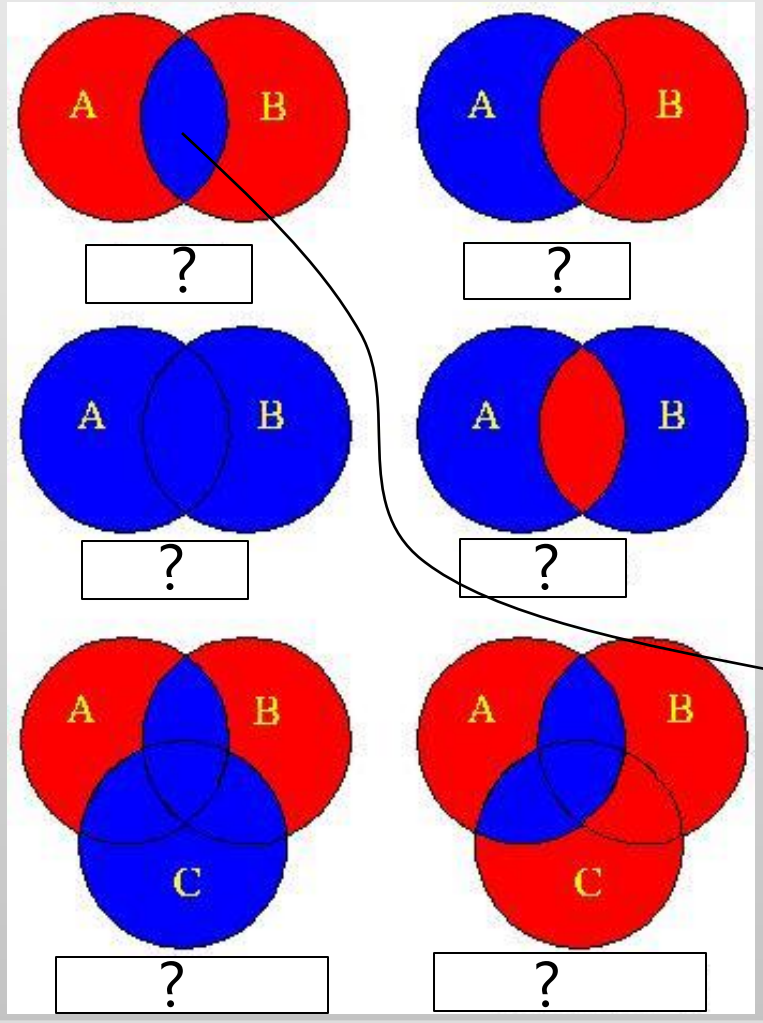
– Build the SQL statement by simply clicking and double-clicking

"POP" > 100,000

logical operator



Attribute operations: Boolean queries

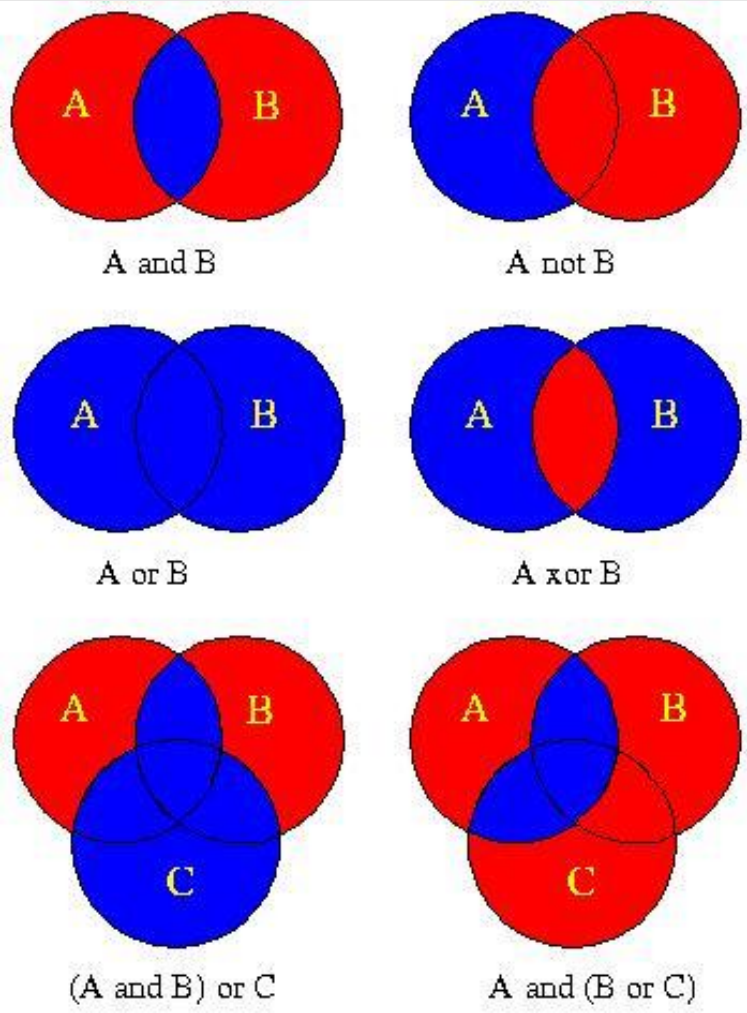


There are 4 basic statements used to get information from 2 (or more) datasets:

- AND
- OR
- NOT
- OR, BUT NOT BOTH (XOR)

What represent the blue area?

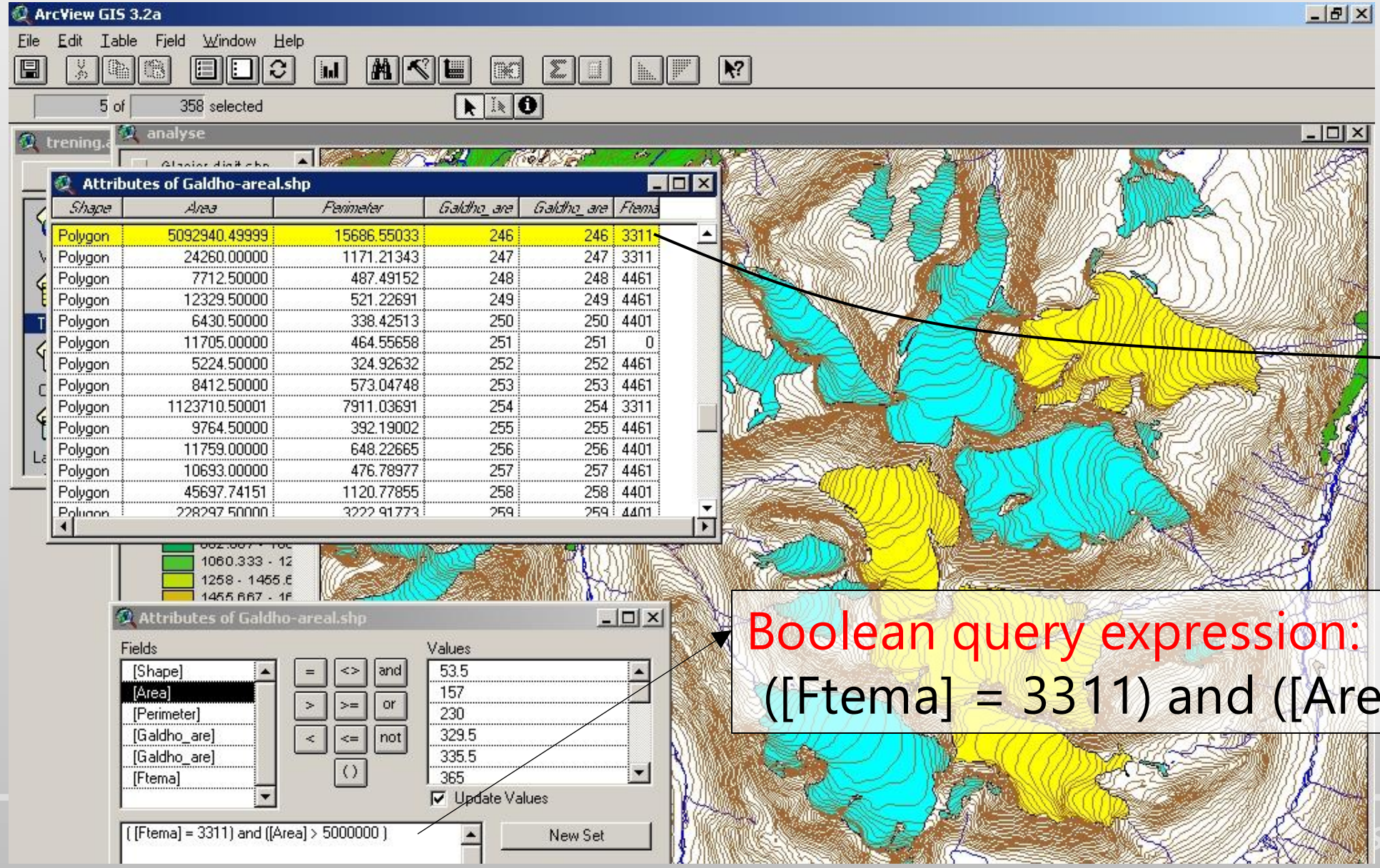
Attribute operations: Boolean queries



There are 4 basic statements used to get information from 2 (or more) datasets:

- AND – subset of each dataset that is 'true' of both datasets
- OR – subset of each dataset that is 'true' of either one or both datasets
- NOT – subset of one dataset that is only true of one dataset
- OR, BUT NOT BOTH (XOR) – subset of data that is 'true' of one and another dataset, but not both datasets

Attribute operations: Boolean queries



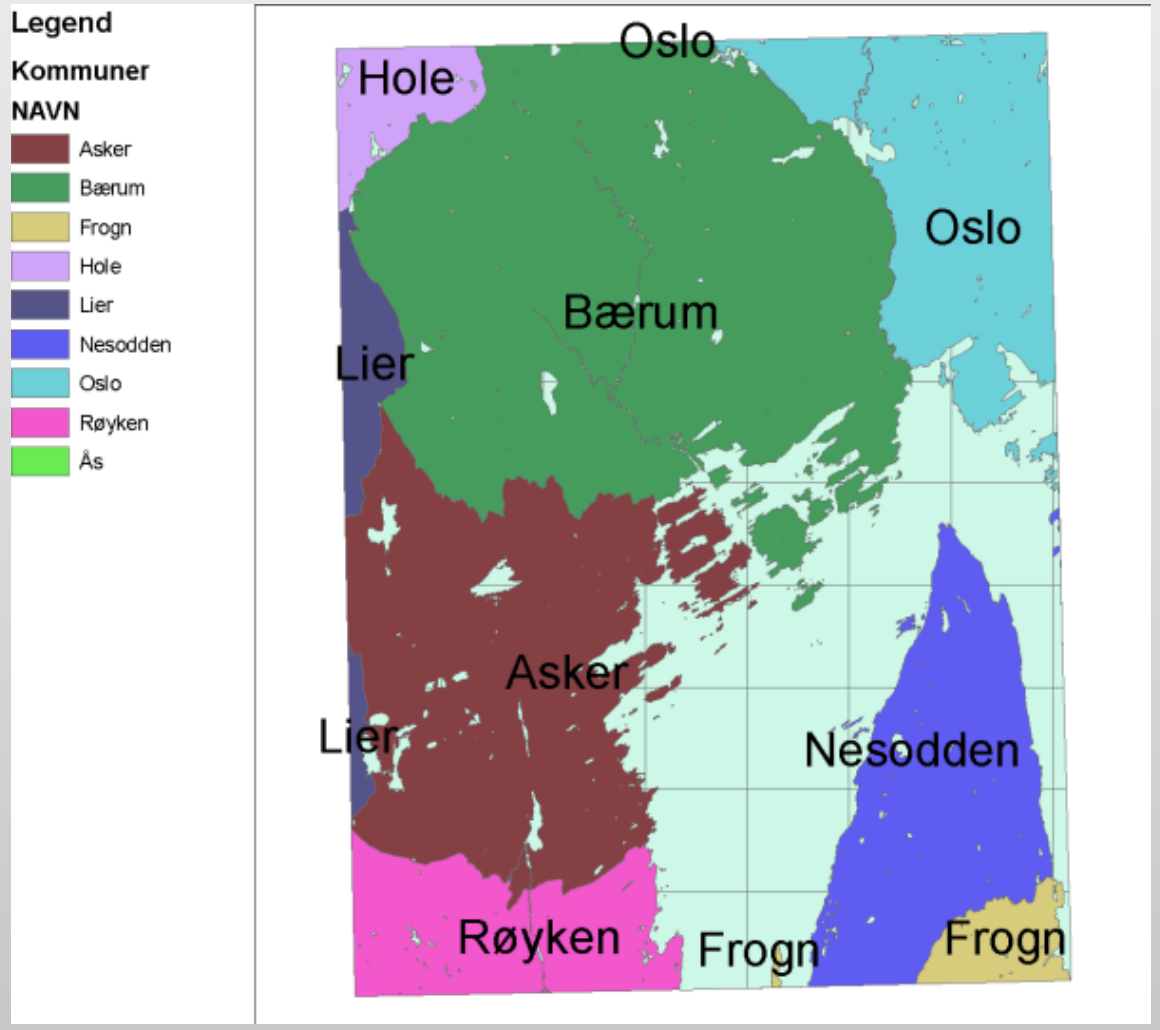
Result Selection

The yellow polygons are the selected

Boolean query expression:

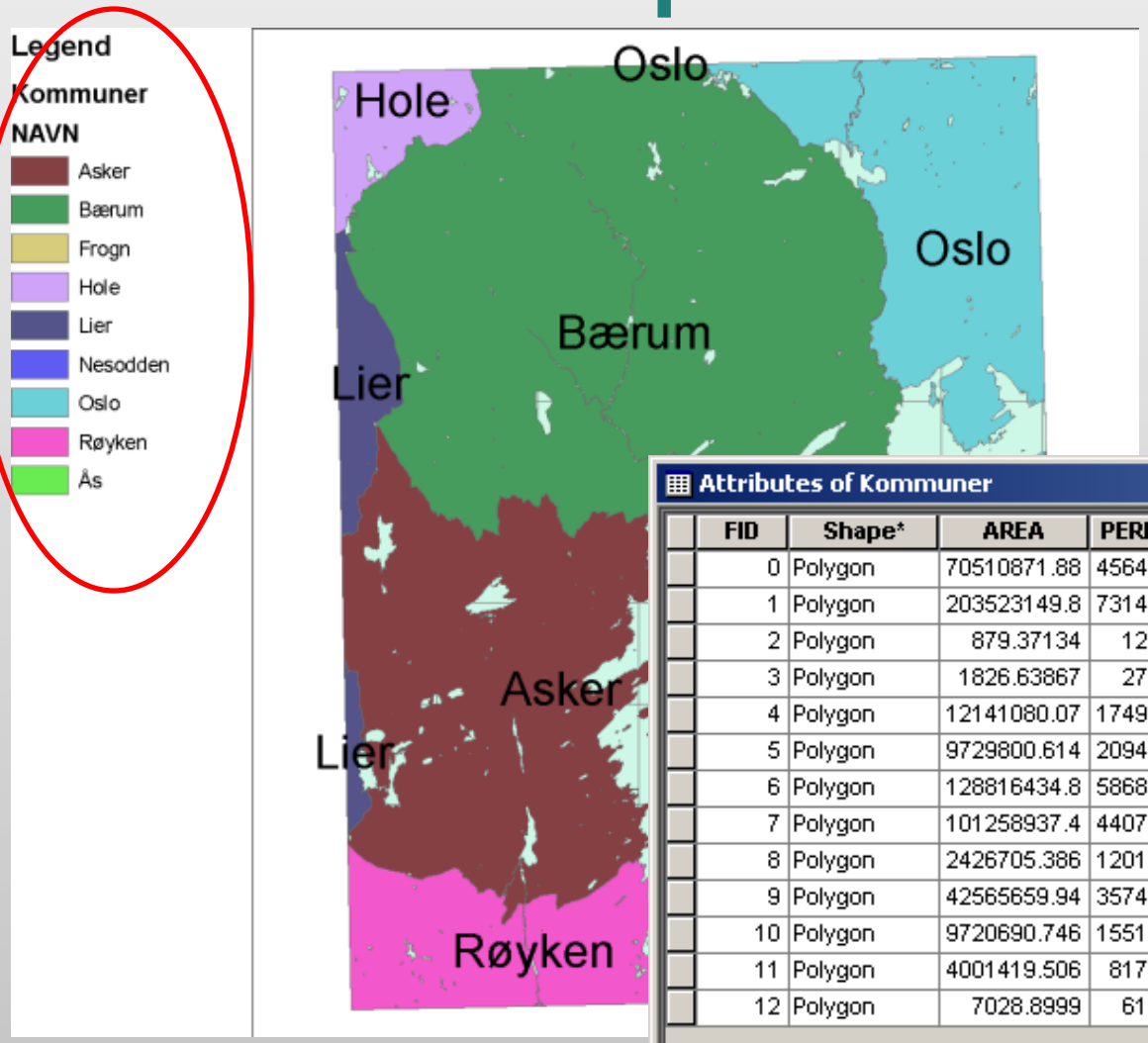
([Ftema] = 3311) and ([Area > 5,000,000])

Attribute operations: Arithmetical operations



- A map of administrative units

Attribute operations: Arithmetical operations



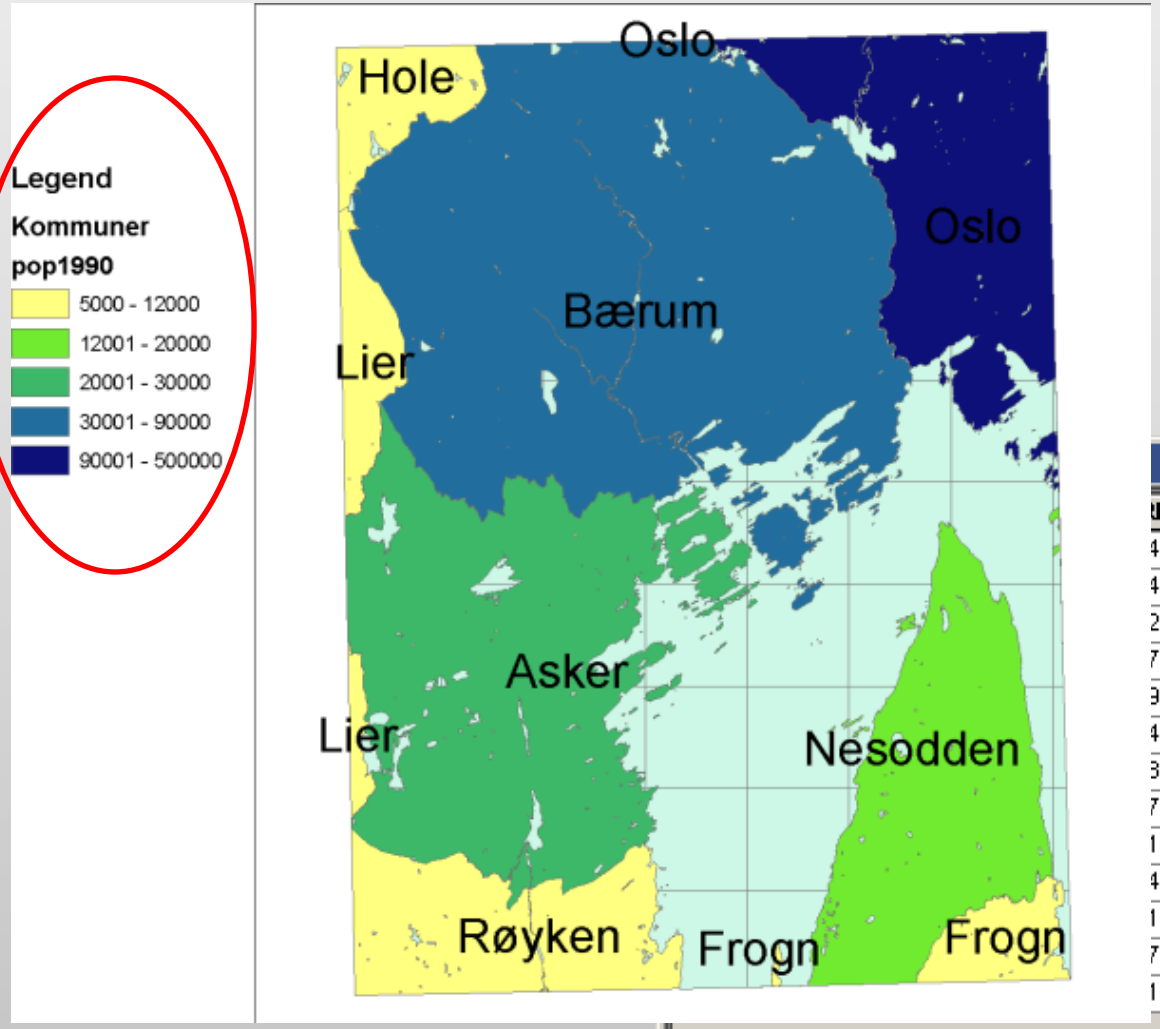
- A map of administrative units
- Also contain population information for two or more years

Attributes of Kommuner

FID	Shape*	AREA	PERIMETER	X	Y	KOORDH	FTEMA	OBJTYPE	KOMM	NAVN	pop1990	pop2000
0	Polygon	70510871.88	45642.61237	595692.42	6651789.76	0	4003	Kommune	301	Oslo	500000	520000
1	Polygon	203523149.8	73143.88496	583770.35	6645851.15	0	4003	Kommune	219	Bærum	90000	110000
2	Polygon	879.37134	126.12199	585248.35	6652340.77	0	4003	Kommune	301	Oslo	500000	520000
3	Polygon	1826.63867	272.58781	584705.01	6652327.63	0	4003	Kommune	301	Oslo	500000	520000
4	Polygon	12141080.07	17498.18809	577089.09	6651262.1	0	4003	Kommune	612	Hole	7000	8000
5	Polygon	9729800.614	20942.37865	576006.27	6643493.51	0	4003	Kommune	626	Lier	5000	5500
6	Polygon	128816434.8	58687.87388	581314.66	6635597.82	0	4003	Kommune	220	Asker	30000	33000
7	Polygon	101258937.4	44078.15212	591965.41	6631713.48	0	4003	Kommune	216	Nesodden	20000	19000
8	Polygon	2426705.386	12016.83169	575558.95	6632335.85	0	4003	Kommune	626	Lier	5000	5800
9	Polygon	42565659.94	35749.16044	580971.28	6625933.1	0	4003	Kommune	627	Røyken	12000	15000
10	Polygon	9720690.746	15513.96649	594475.21	6625713.4	0	4003	Kommune	215	Frogn	8000	8800
11	Polygon	4001419.506	8171.40447	587393.4	6625392.48	0	4003	Kommune	215	Frogn	8000	8800
12	Polygon	7028.8999	618.49703	596509.52	6625549.93	0	4003	Kommune	214	Ås	11000	11500

Record: 0 Show: All Selected Records (0 out of 13 Selected.) Options

Attribute operations: Arithmetical operations

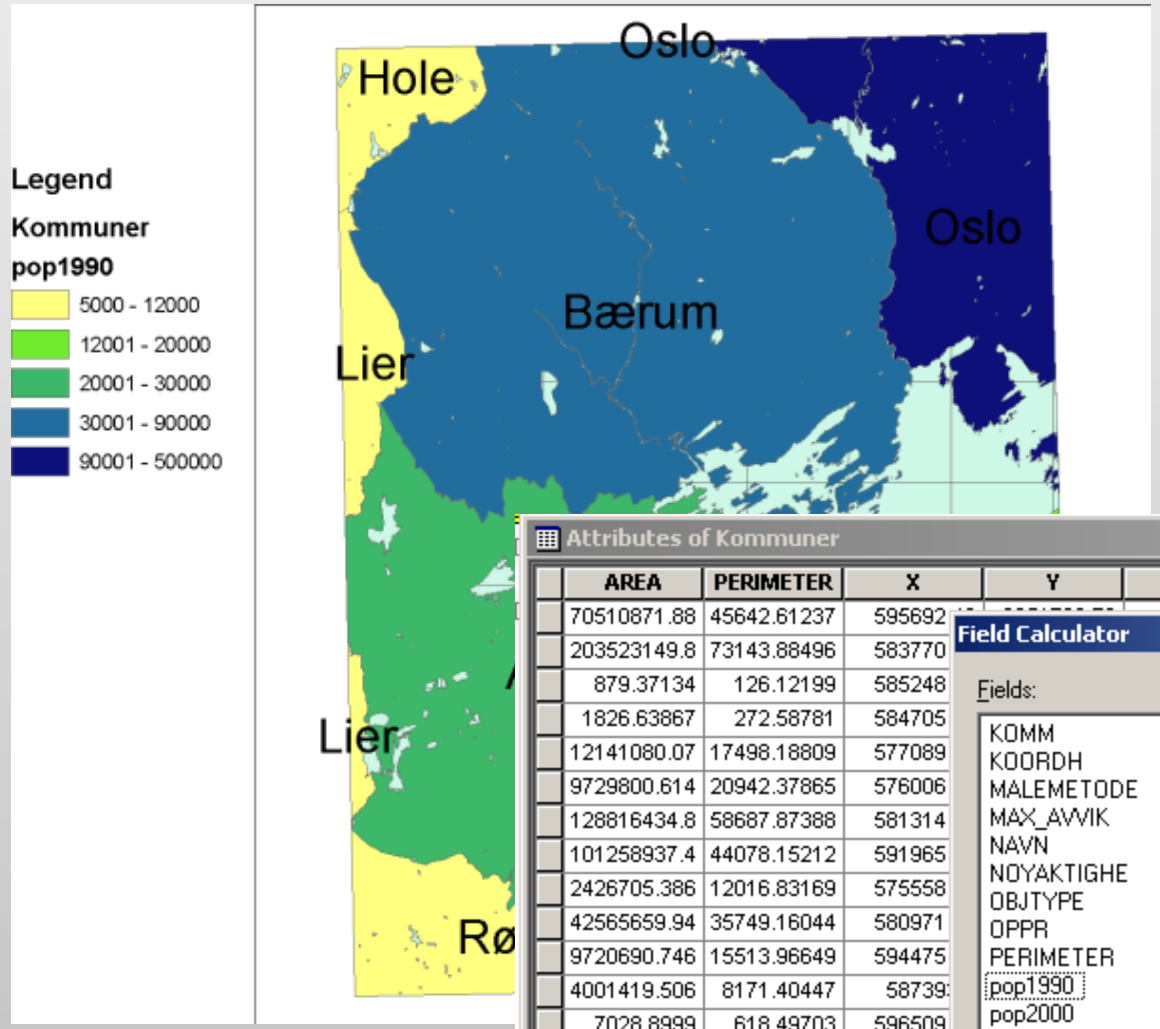


- This allow us to display the population as graded colors

UMETER	X	Y	KOORDH	FTEMA	OBJTYPE	KOMM	NAVN	pop1990	pop2000
42.61237	595692.42	6651789.76	0	4003	Kommune	301	Oslo	500000	520000
43.88496	583770.35	6645851.15	0	4003	Kommune	219	Bærum	90000	110000
26.12199	585248.35	6652340.77	0	4003	Kommune	301	Oslo	500000	520000
72.58781	584705.01	6652327.63	0	4003	Kommune	301	Oslo	500000	520000
98.18809	577089.09	6651262.1	0	4003	Kommune	612	Hole	7000	8000
42.37865	576006.27	6643493.51	0	4003	Kommune	626	Lier	5000	5500
37.87388	581314.66	6635597.82	0	4003	Kommune	220	Asker	30000	33000
78.15212	591965.41	6631713.48	0	4003	Kommune	216	Nesodden	20000	19000
16.83169	575558.95	6632335.85	0	4003	Kommune	626	Lier	5000	5800
49.16044	580971.28	6625933.1	0	4003	Kommune	627	Røyken	12000	15000
13.96649	594475.21	6625713.4	0	4003	Kommune	215	Frogn	8000	8800
71.40447	587393.4	6625392.48	0	4003	Kommune	215	Frogn	8000	8800
18.49703	596509.52	6625549.93	0	4003	Kommune	214	Ås	11000	11500

Record: 0 Show: All Selected Records (0 out of 13 Selected.) Options

Attribute operations: Arithmetical operations



- **Operation:** calculate the change in population between 2000 and 1990

Query expression:
[pop2000] – [pop1990]

Output (new attribute): popdiff

Attributes of Kommuner

AREA	PERIMETER	X	Y	KOORDH	FTEMA	OBJTYPE	KOMM	NAVN	pop1990	pop2000	popdiff
70510871.88	45642.61237	595692								520000	20000
203523149.8	73143.88496	583770								110000	20000
879.37134	126.12199	585248								520000	20000
1826.63867	272.58781	584705								520000	20000
12141080.07	17498.18809	577089								8000	1000
9729800.614	20942.37865	576006								5500	500
128816434.8	58687.87388	581314								33000	3000
101258937.4	44078.15212	591965								19000	-1000
2426705.386	12016.83169	575558								5800	800
42565659.94	35749.16044	580971								15000	3000
9720690.746	15513.96649	594475								8800	800
4001419.506	8171.40447	58739								8800	800
7028.8999	618.49703	596509								11500	500

Record: 0

Field Calculator

Fields:
KOMM
KOORDH
MALEMETODE
MAX_AVVIK
NAVN
NOYAKTIGHE
OBJTYPE
OPPR
PERIMETER
pop1990
pop2000
popdiff

Type: Number / String / Date

Functions: Abs ( ), Atn ( ), Cos ( ), Exp ( ), Fix ( ), Int ( ), Log ( ), Sin ( ), Sqr ( )

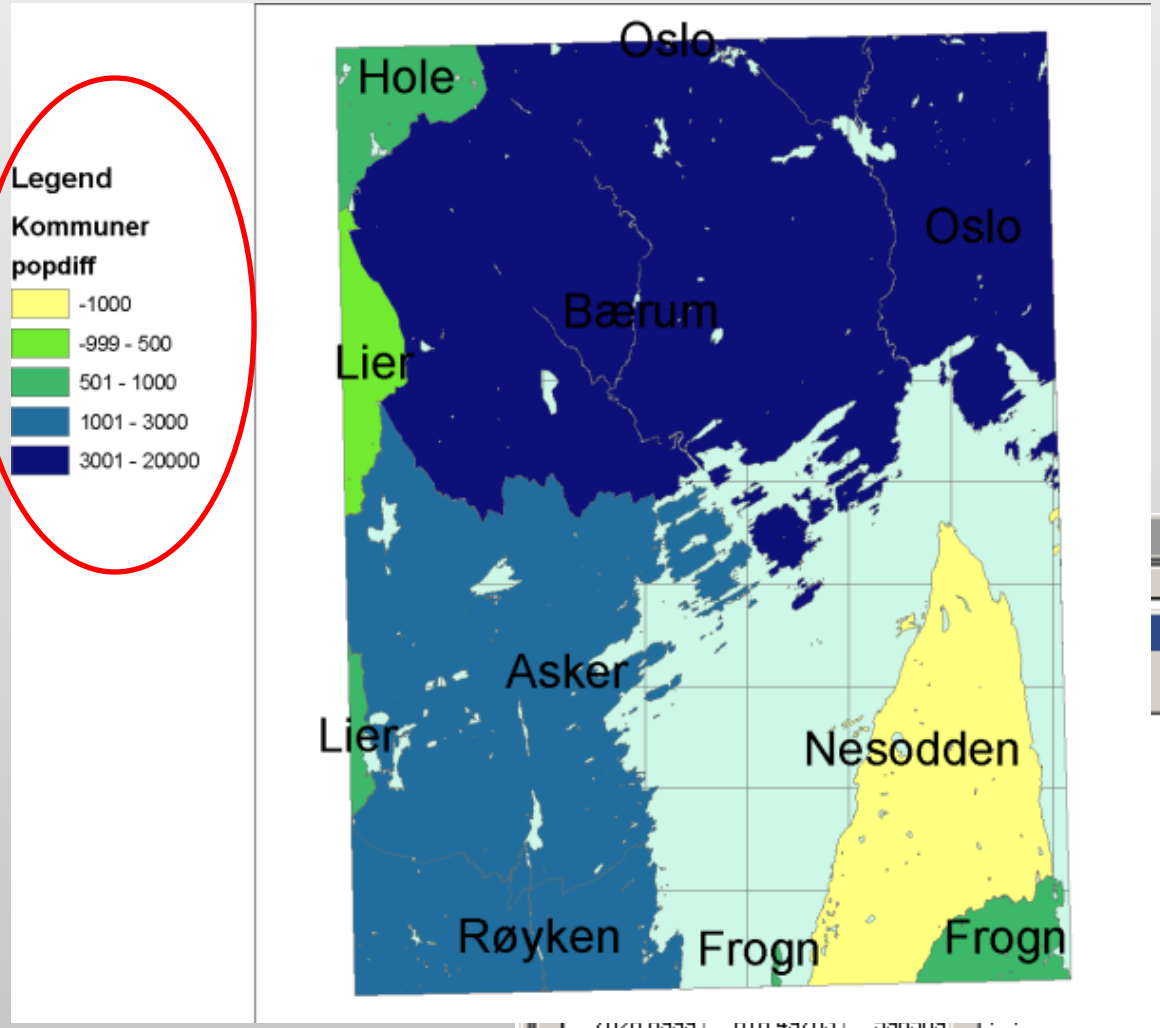
× / & + - =

popdiff = [pop2000] - [pop1990]

Advanced

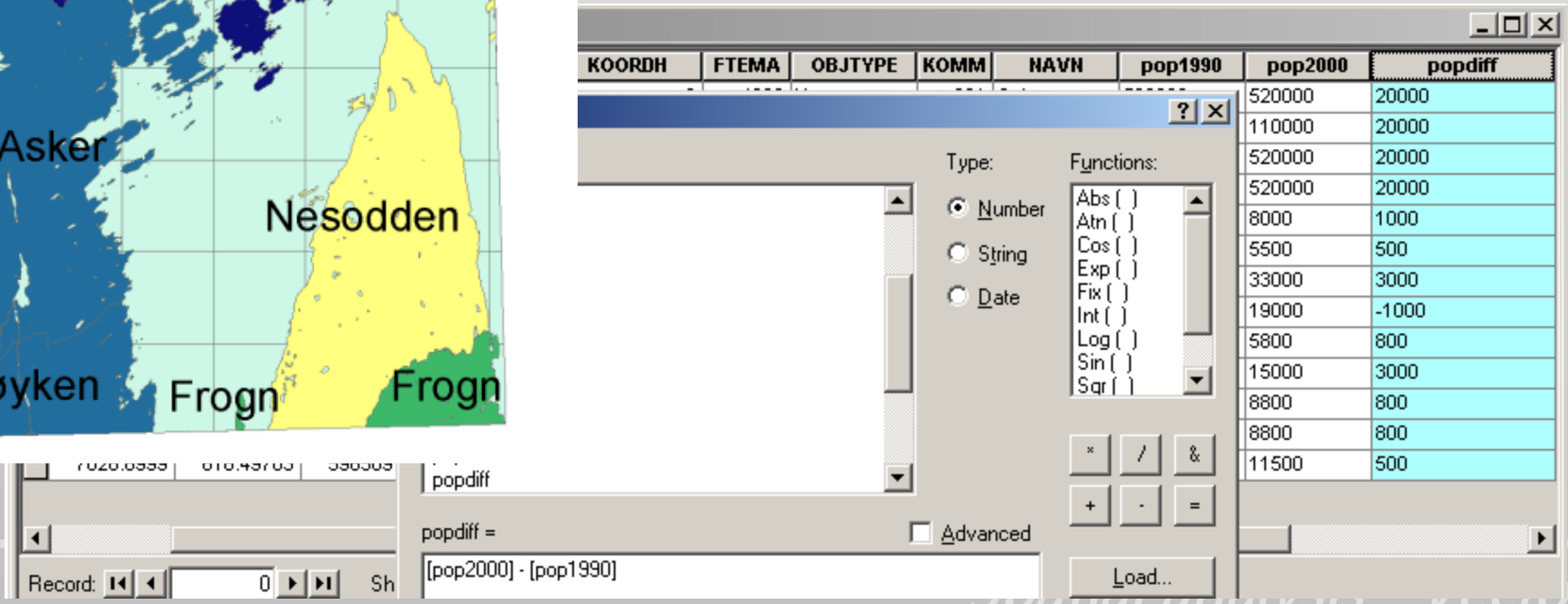
Load...

Attribute operations: Arithmetical operations

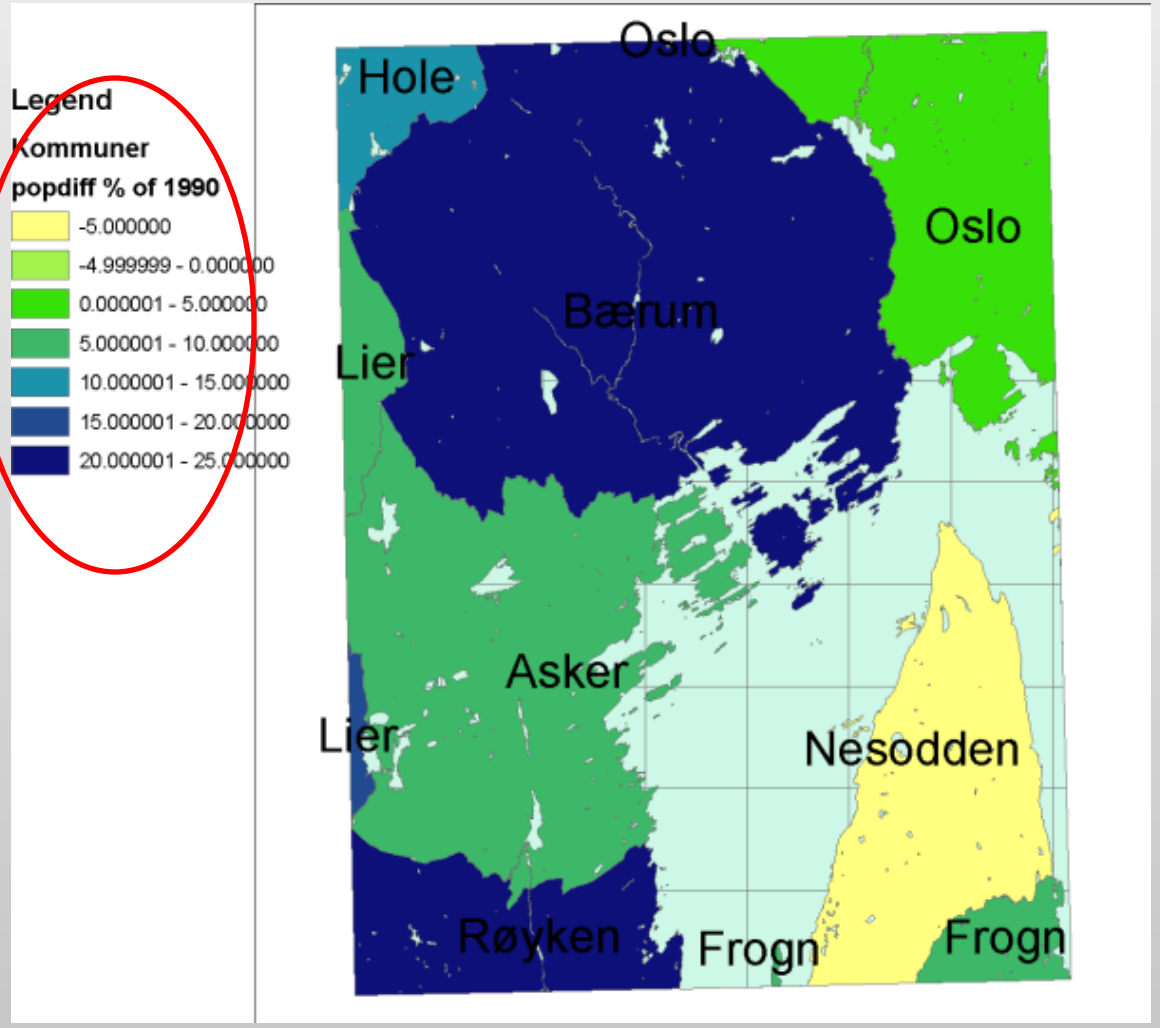


- Display this attribute in different ways:

1. **Classes**



Attribute operations: Arithmetical operations

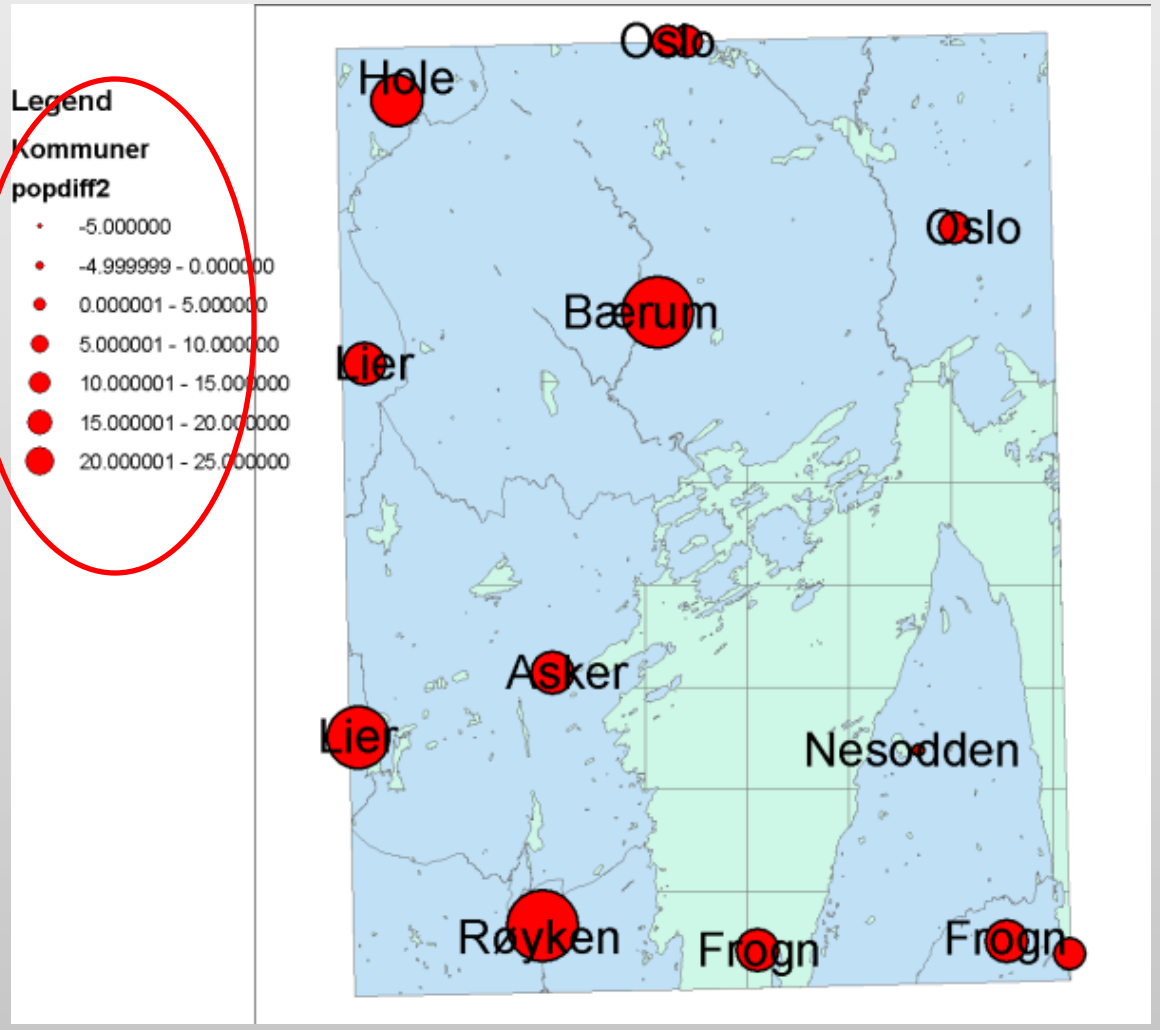


- Display this attribute in different ways:

2. Graduated colors

(percent of population of 1990)

Attribute operations: Arithmetical operations



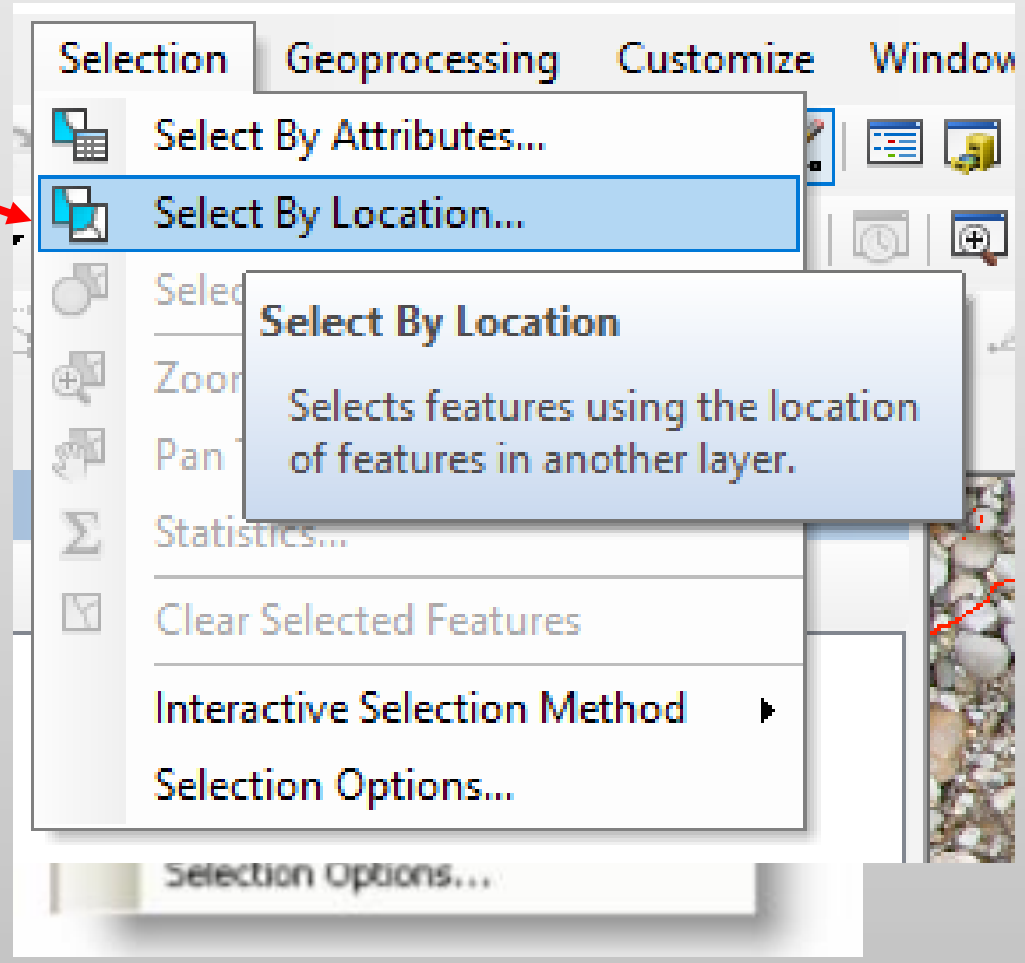
- Display this attribute in different ways:

3. Graduated symbols

(percent of population of 1990)

Attribute operations: Queries, selection

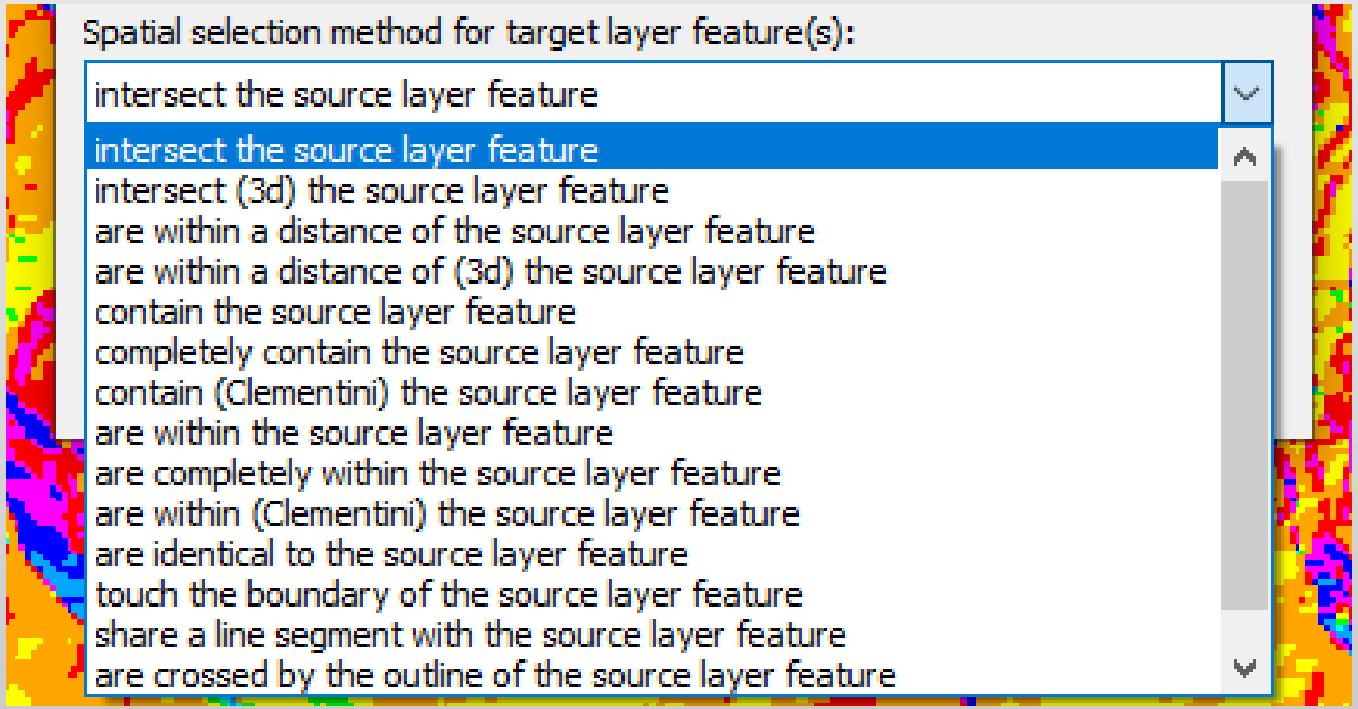
- By Location (Spatial query)



Attribute operations: Queries, selection

- **By Location (Spatial query)**
  - Intersect
  - within distance of
  - Completely contain
  - Are completely within
  - Have their center in
  - Touch the boundary of

Relationships between layers (that you can specify)



https://desktop.arcgis.com/en/arcmap/latest/map/working-with-layers/using-select-by-location.htm

Types of analysis

- Attribute operations
  - Query / selection
    - based on attribute
    - based on location
  - Aggregation:
    - reclassification
    - removal of common boundaries
  - Overlay: union, clipping and intersect
  - Statistical operations (classification, regression, etc.)

Attribute operations: Aggregation

- Grouping operation
- Simplifies the dataset by merging identical objects
- Connects adjacent polygons with similar properties (reclassification), and removes common boundaries

- Vector:

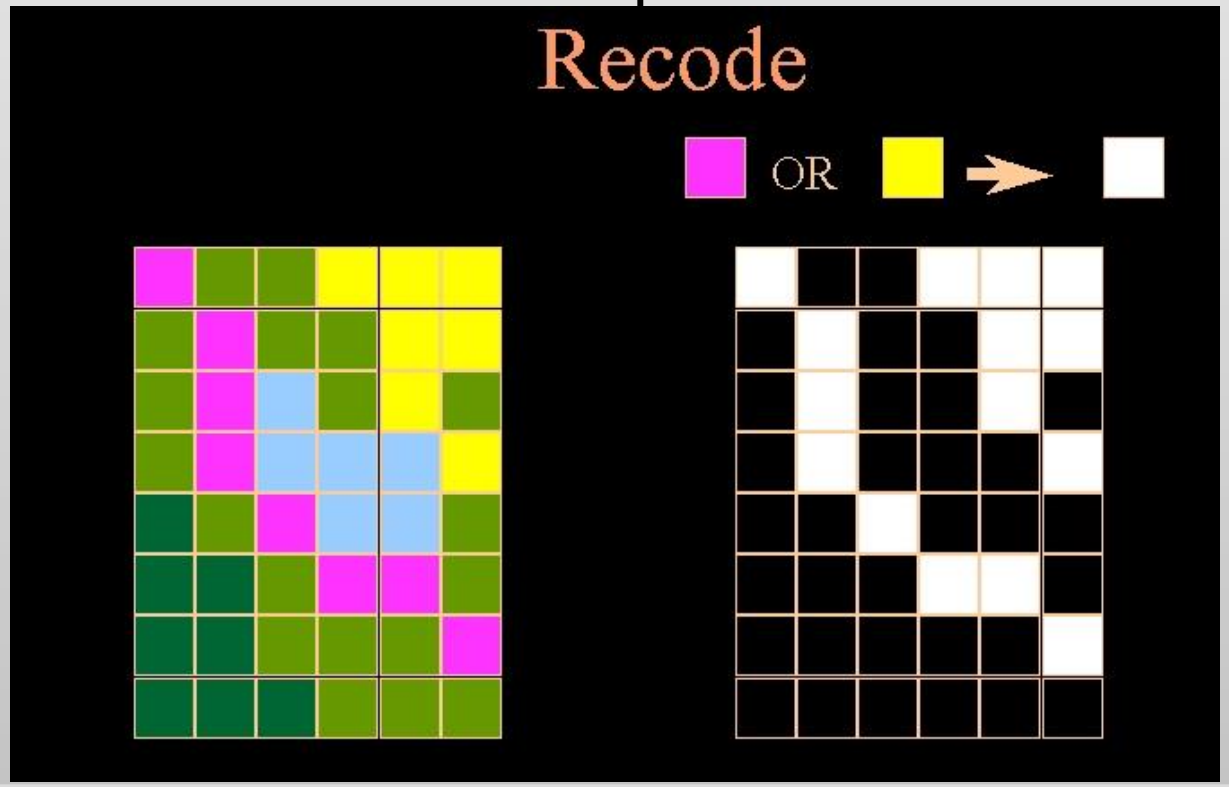
Ex: Create new common attributes and remove old boundaries

- Raster:

Ex: Give equal pixel values within each area that is aggregated

Attribute operations: Aggregation

- **Reclassification**:
  - Merge pixel values (raster) or attributes (vector)
  - Can use boolean operations in the assignment

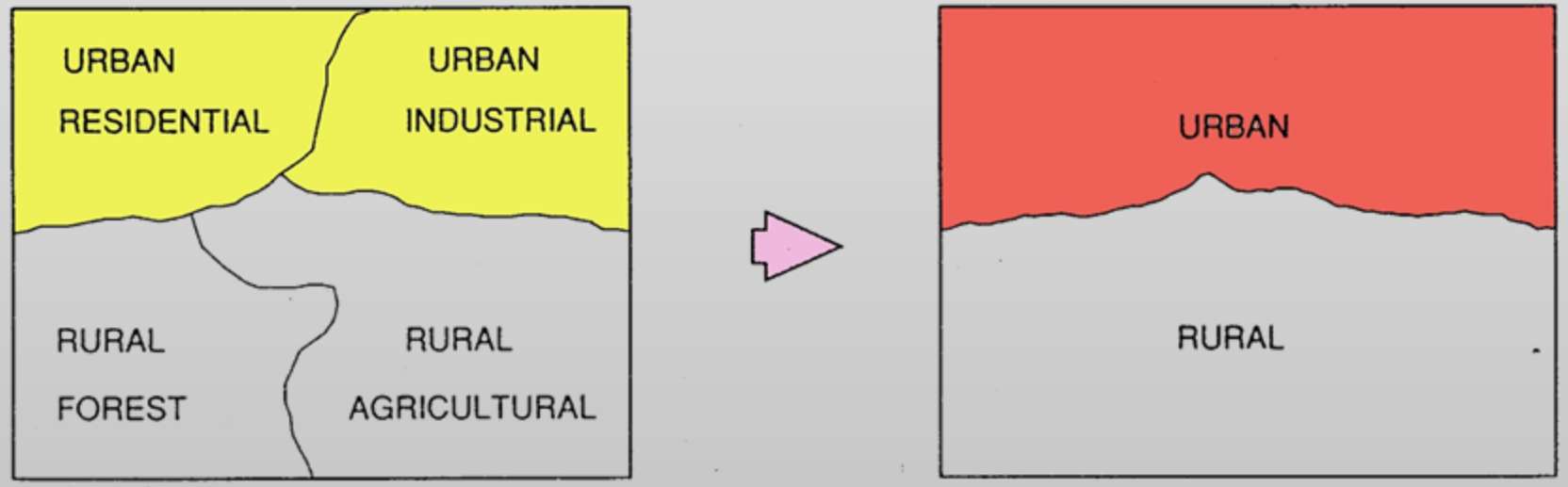


Example of raster reclassification using a Boolean operation

Attribute operations: Aggregation

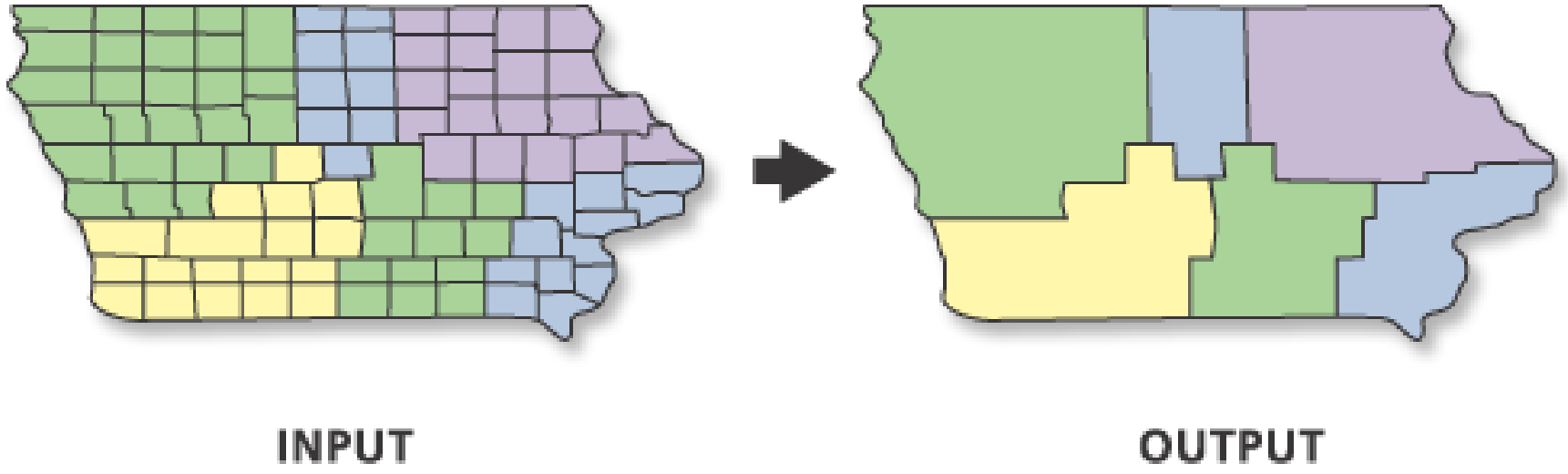
- **Reclassification**:
  - Merge pixel values (raster) or objects (vector)
  - Useful for creating new and simplified classes

Example of vector reclassification to simplify classes



Attribute operations: Aggregation

- **Dissolve operation**:
  - The dissolve function aggregate neighboring polygons with the same attribute value (the borders between them are dissolved)
  - Change in geometry based on common attribute values



Example: simplifies datasets after a reclassification

Types of analysis

- Attribute operations
  - Query / selection
    - based on attribute
    - based on location
  - Aggregation:
    - reclassification
    - removal of common boundaries
  - Overlay: union, clipping and intersect
  - Statistical operations (classification, regression, etc.)

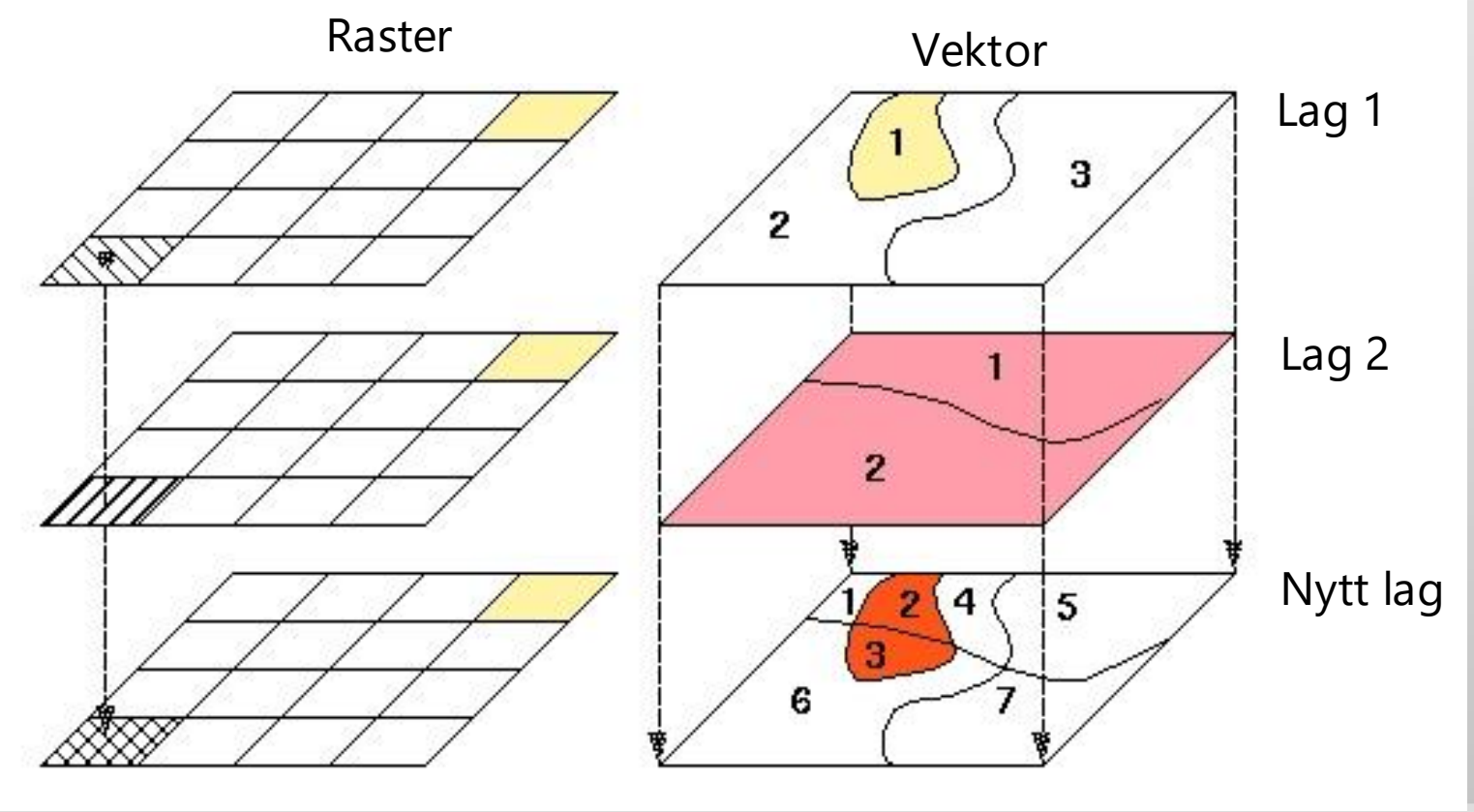
Attribute operations: Overlay

- Combine multiple layers of data into a new layer
- Properties are passed on and a new topology is formed

Definition: Overlay is a GIS operation that superimposes multiple data sets (representing different themes) together for the purpose of identifying relationships between them.

Attribute operations: Overlay

- Combine multiple layers of data into a new layer
- Properties are passed on and a new topology is formed



Attribute operations: Overlay

- Combine different data layers to study contexts
- Create new objects with multiple properties / attributes
- Perform statistical analyses of combined layers
- Create new delimitations for the objects

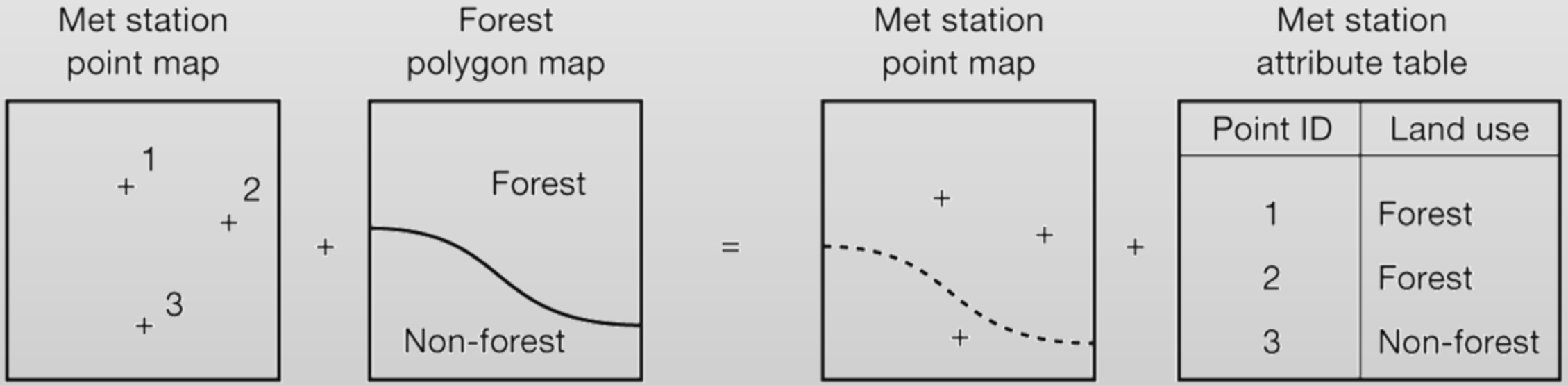
- *Examples:*
  - Analyse connections between different layers
  - Suitability analysis of area for a given purpose
  - Mapping changes over different time (overlay maps from different times)

Attribute operations: Overlay vector

- To overlay, the input layers must:
  - have consistent topology
  - be in the same reference system
- The new layer inherits and combines all topology from the input layers:
  - new and more complex topology
  - Intersection between all lines and polygon is calculated -> nodes
  - New polygons become new objects that must have unique ID number
  - The attribute tables can also be linked together
- Complex and heavy calculation in relation to raster

Attribute operations: Overlay vector

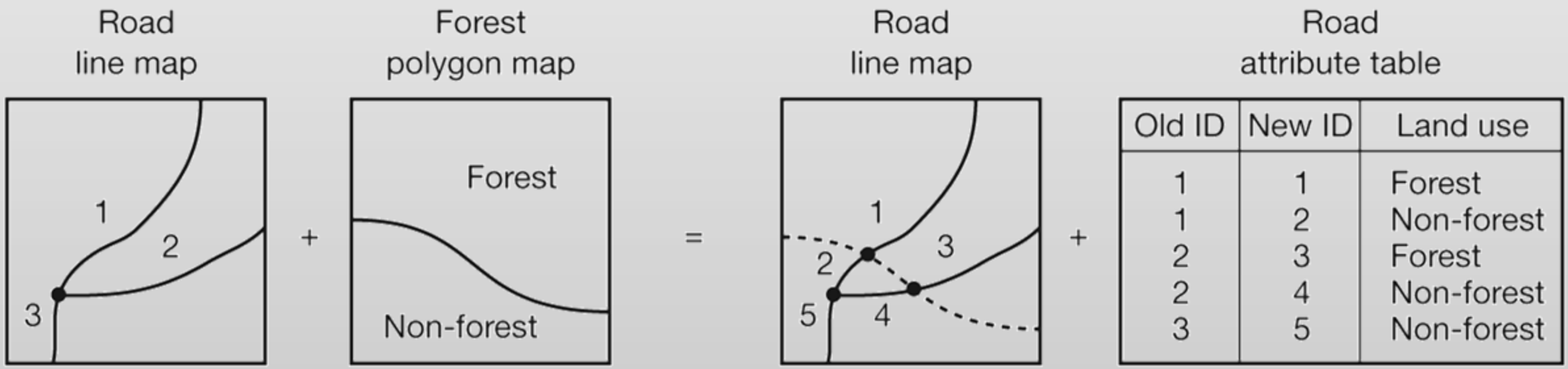
Vector overlays: points-in-polygon



Heywood *et al.*, An Introduction to Geographical Information Systems, 2/e

Attribute operations: Overlay vector

Vector overlays: lines-in-polygon



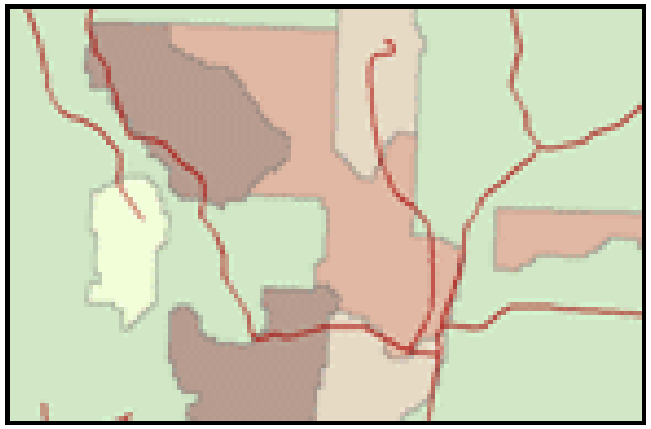
Old ID	New ID	Land use
1	1	Forest
1	2	Non-forest
2	3	Forest
2	4	Non-forest
3	5	Non-forest

Heywood *et al.*, An Introduction to Geographical Information Systems, 2/e

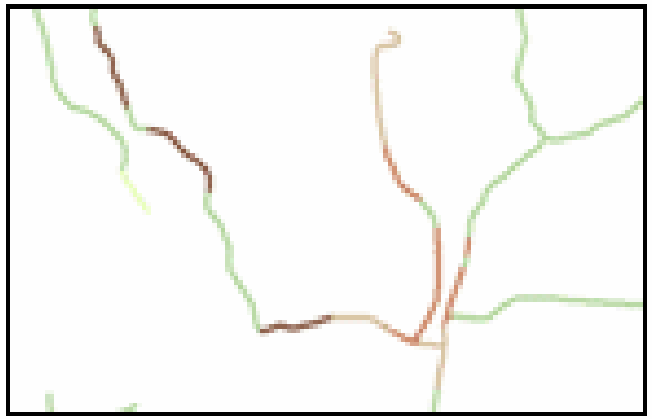
NOTE: Overlay builds topology! Example: find lines in polygon (content)

Attribute operations: Overlay vector

Vector overlays: lines-in-polygon



=



Lines → logging roads

Polygons → vegetation types

	FID	Shape*	LOCALID	RD_TYPE
	6	Polyline	222192	1500
	7	Polyline	220833	1500

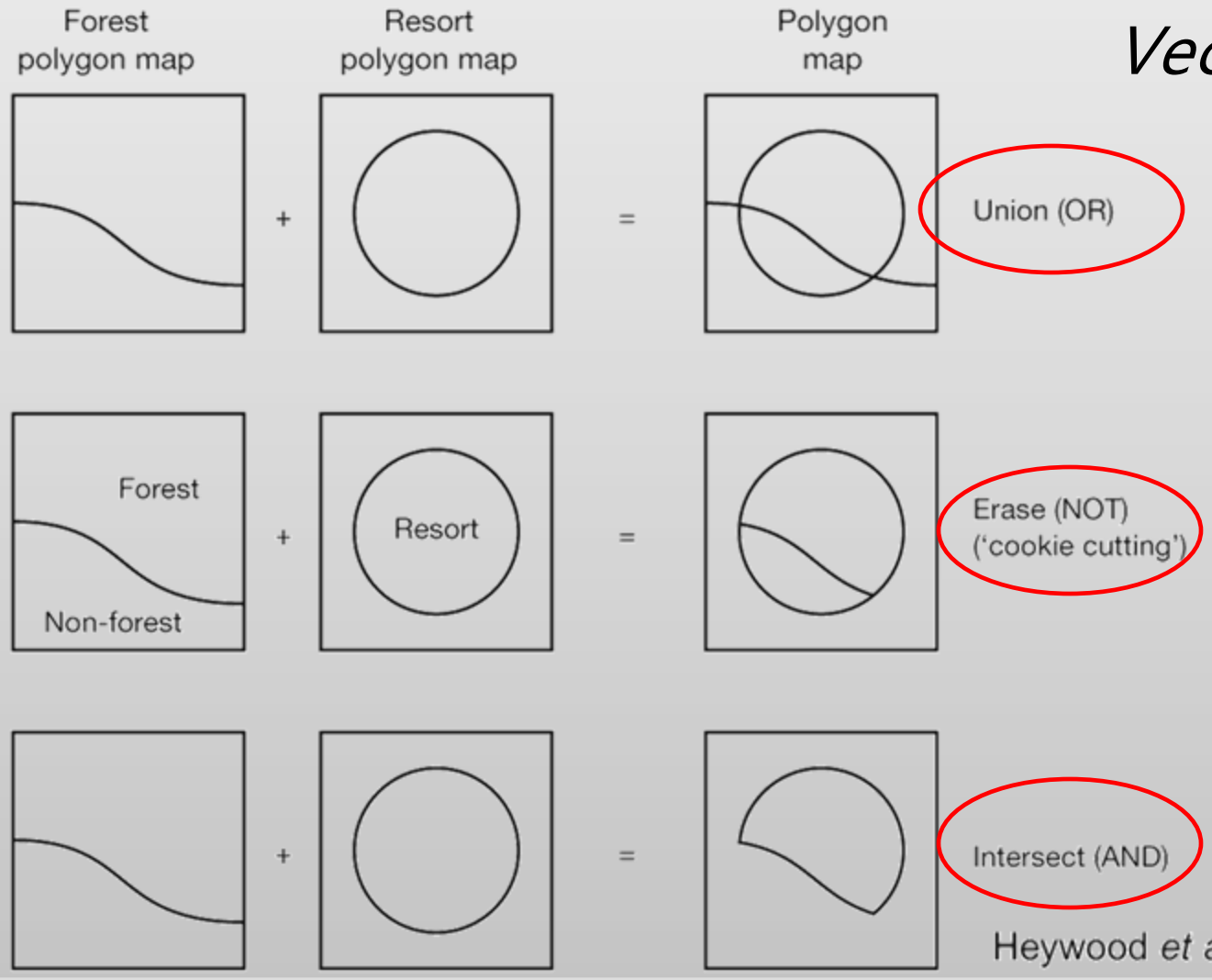
+

	FID	Shape*	VEG_TYPE
	6	Polygon	CC
	7	Polygon	SO
	8	Polygon	SS

	FID	Shape*	LOCALID	RD_TYPE	VEG_TYPE
	6	Polyline	219378	1500	FC
	7	Polyline	219384	1500	FC
	8	Polyline	219380	1500	FC
	9	Polyline	219382	1500	SO
	10	Polyline	224631	1500	FC

Attribute operations: Overlay vector

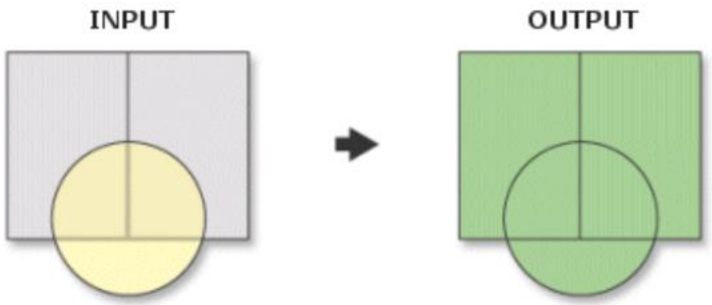
Vector overlays: polygon-on-polygon



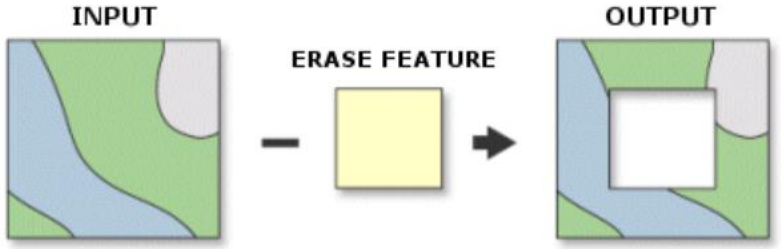
Heywood *et al.*, An Introduction to Geographical Information Systems, 2/e

Attribute operations: Overlay vector

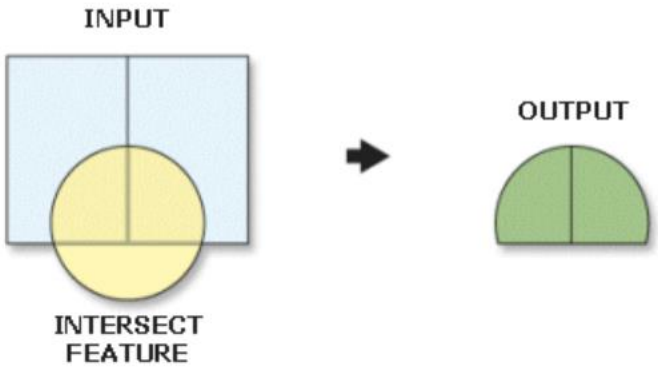
Union



Erase



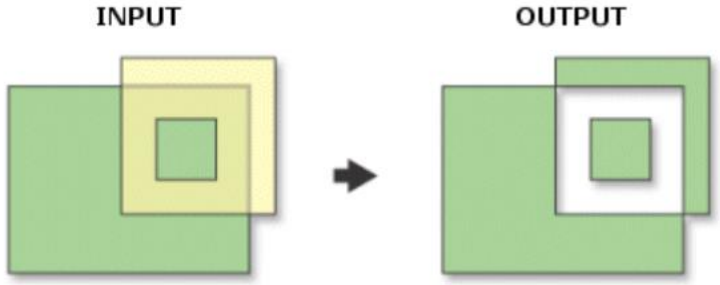
Intersect



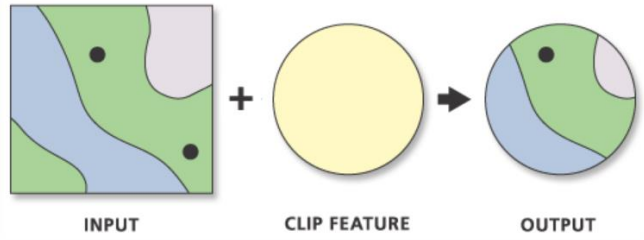
Vector overlays: polygon-on-polygon

https://desktop.arcgis.com/en/arcmap/10.3/tools/analysis-toolbox/an-overview-of-the-overlay-toolset.htm

Symmetrical Difference



Clipping



https://desktop.arcgis.com/en/arcmap/10.3/tools/analysis-toolbox/clip.htm

Attribute operations: Overlay vector

- **Overlay is a tool for analysis and presentation**
- Overlapped maps are a bad storage structure!
  - Visual and storage complexity
  - Many double stores of attributes
  - Difficult to make updates
  - Difficult to do other analyzes

- Different analyzes -> different overlay strategies
- A layered data structure provides the greatest flexibility!

- Problem with spurious polygons

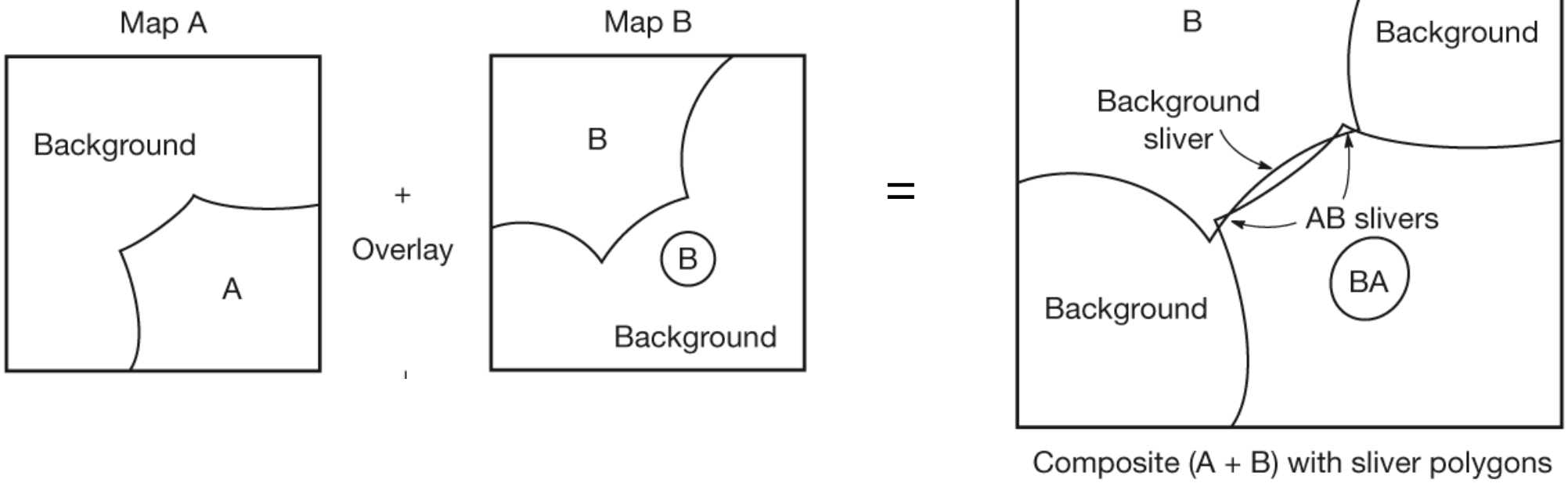
Attribute operations: Overlay vector

- **Overlay: Spurious polygons**
  - Topological overlay may lead to the creation of spurious polygons because boundaries that are supposed to lie in the same place doesn't
  - This can be due to:
    - Digitising errors
    - Scale effects (combining maps with different level of spatial generalisation)
    - Combining of data from different sources/users

Attribute operations: Overlay vector

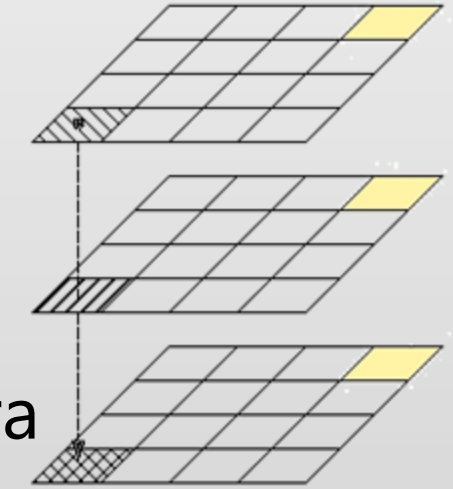
Overlay: Spurious polygons

Generation of slivers polygons



Heywood *et al.*, An Introduction to Geographical Information Systems, 2/e

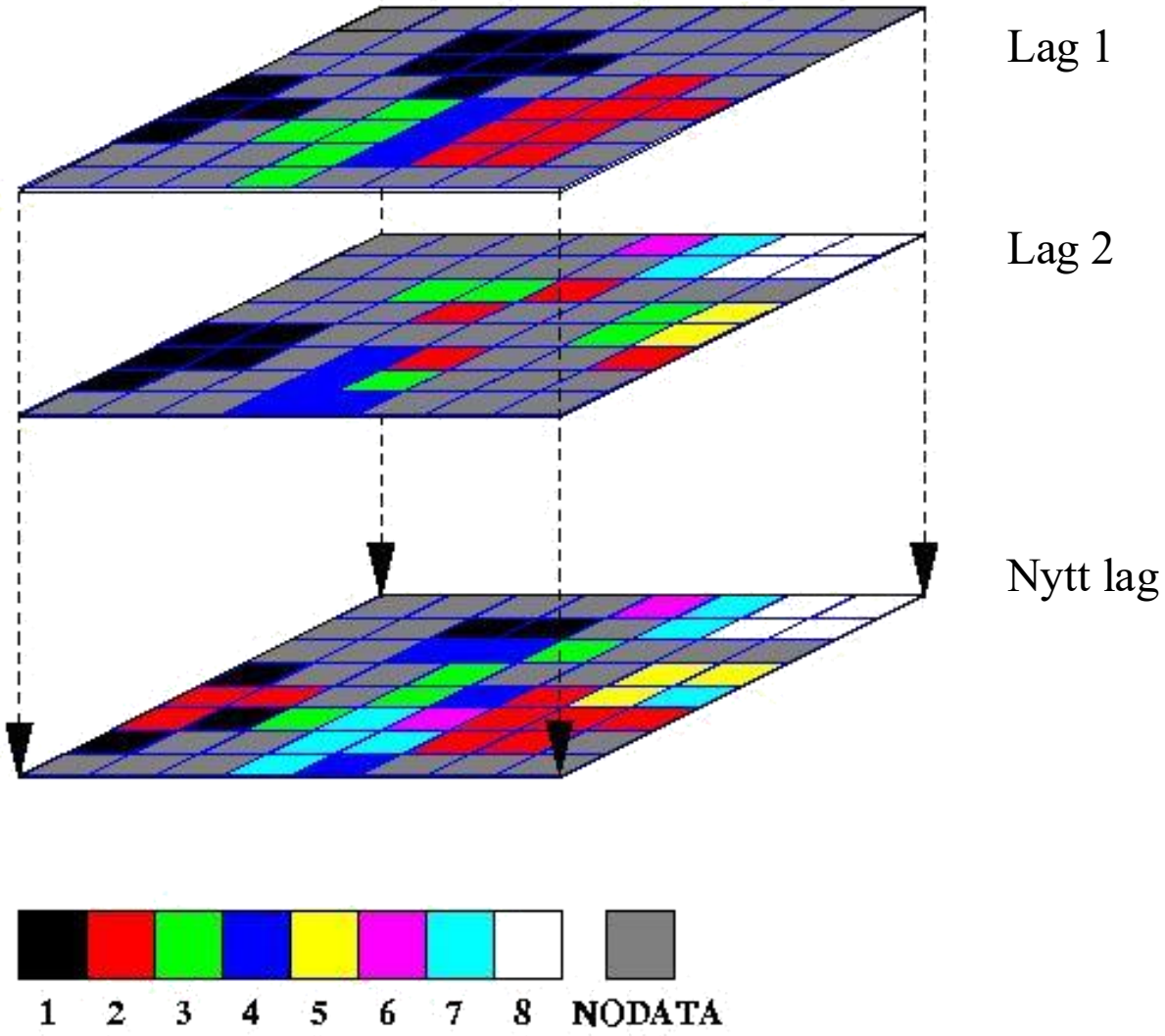
Attribute operations: Overlay raster



- To overlay, the input layers must:
  - Be in the same reference system
  - Have overlapping raster cells with equal resolution
    - possibly resampling to get the same raster resolution
- Coherent pixels in each layer are combined using algebra (mathematical operations):
  - Addition, subtraction, multiplication, division, mean value, …
  - New raster pixel values should have a common measurement level and scale
- Simple and fast calculation in relation to vector
- Few analysis options!

Attribute operations: Overlay raster - add

Example of adding pixel values in a overlay raster



Attribute operations: Overlay raster - add

Raster overlays: using addition

Use: find change in the landscape or change detection

Forestry

0	5	5
0	0	0
5	5	5

Forest = 5
Other areas = 0

+

Happy Valley Resort

10	10	10
10	10	0
0	0	0

Resort area = 10
Other area = 0

=

Result

10	15	15
10	10	0
5	5	5

Neither forest nor resort = 0
Forest, not in resort = 5
Resort, no forest = 10
Forest in resort area = 15

Attribute operations: Overlay raster - add

Raster overlays: using addition

Forest in 1999

3	5	5
3	3	5
5	5	5

Forest in 2015

5	5	5
3	3	3
5	3	5

Forest change between 1999 and 2015

8	10	10
6	6	8
10	8	10

3	Bare land
5	Forested Land

8	Bare to forest
6	Bare – no change
10	Forest – no change

Attribute operations: Overlay raster

- Algebra:

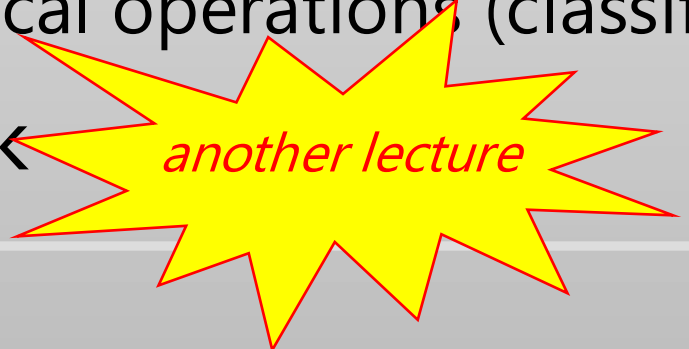
Type of function	Example Operations	Example Use
Arithmetic	Add, Subtract, Multiply, Divide	Finding total risk out of individual risk factors
Statistics	Minimum, Maximum, Mean, Median	Finding statistical trends
Relational Operations	Greater than, less than, equal to	Comparing values, finding all cells = X
Boolean	Not, And, Or	Can be used in combination with relational operators; find all cells = X and cells = Y
Trigonometry	Sine, Cosine, Tangent, Arcsine	
Exponential and logarithmic	Exponents and Logs	

Types of analysis

- Attribute operations
  - Query / selection
    - based on attribute
    - based on location
  - Aggregation:
    - reclassification
    - removal of common boundaries
  - Overlay: union, clipping and intersect
  - Statistical operations (classification, regression, etc.)

Types of analysis / basic operations: summary

- Geometric operations
  - Distance, perimeter, area, lines, directions, objects/points, etc.
  - Buffers
- Attribute operations
  - Query / selection
    - Based on attribute and based on location
  - Aggregation: Reclassification and removal of common boundaries
  - Overlay: union, clipping and intersect
  - Statistical operations (classification, regression, etc.)
- Network



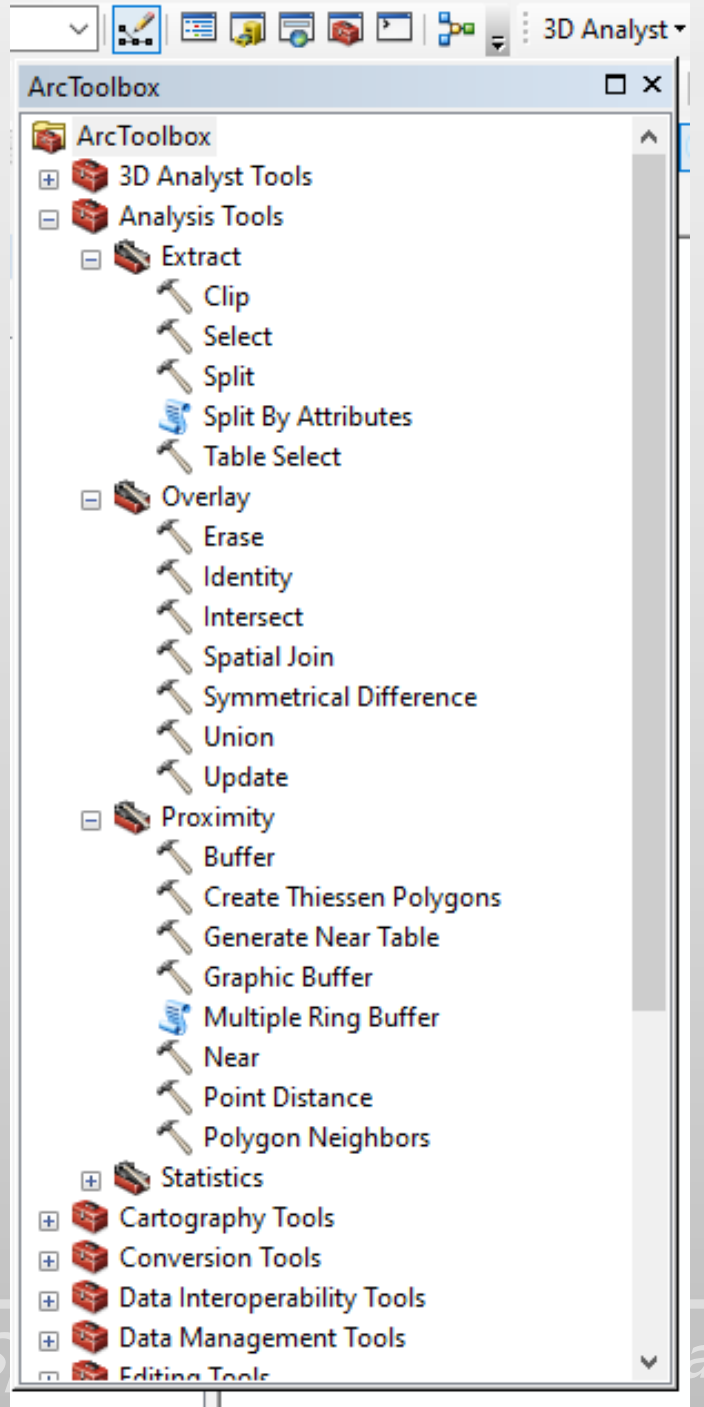
Types of analysis / basic operations: summary

- Scripting
  - When a complex series of commands must be used frequently to retrieve and transform data (e.g. buffer, overlay, new attributes) it is sensible to create a structures command file

→ **Multi-criteria analysis (MCA) is a technique used to consider many different criteria when making a decision.**

Analysis tool summary

- Types of geoprocessing operations (Multiple Layer Operations):
  - Buffer
  - Dissolve
  - Append (spatial join)
  - Clip
  - Intersect
  - Union
  - Erase



Thanks!

Feedback questions