Overlay analysis and Map Algebra

Spatial Data Analysis and Simulation modelling, 2020, Simon Scheider

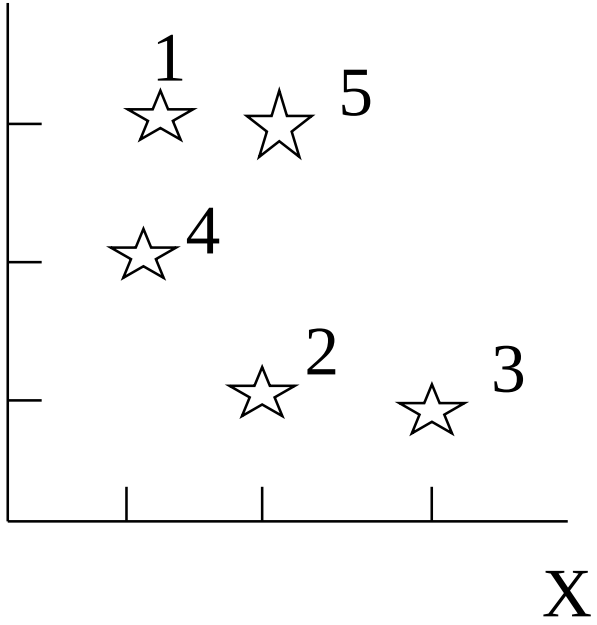
Outline

- Vector Overlay and Analysis:
  - Spatial relations
  - Selection
  - Overlay
  - Spatial Join
- Raster Overlay and Analysis:
  - Local map algebra
  - Zonal map algebra

Vector Overlay and Analysis

Vector data format

e.g. point data



Objects have unique identifiers--
point ID, polygon ID, arc ID, etc

common identifiers provide link to:

–geometry table (for ‘where)

–attributes table (for what)

Coordinates Table		
Point ID	x	y
1	1	3
2	2	1
3	4	1
4	1	2
5	3	2

Attributes Table		
Point ID	model	year
1	a	90
2	b	90
3	b	80
4	a	70
5	c	70

Relational (table based) data representation

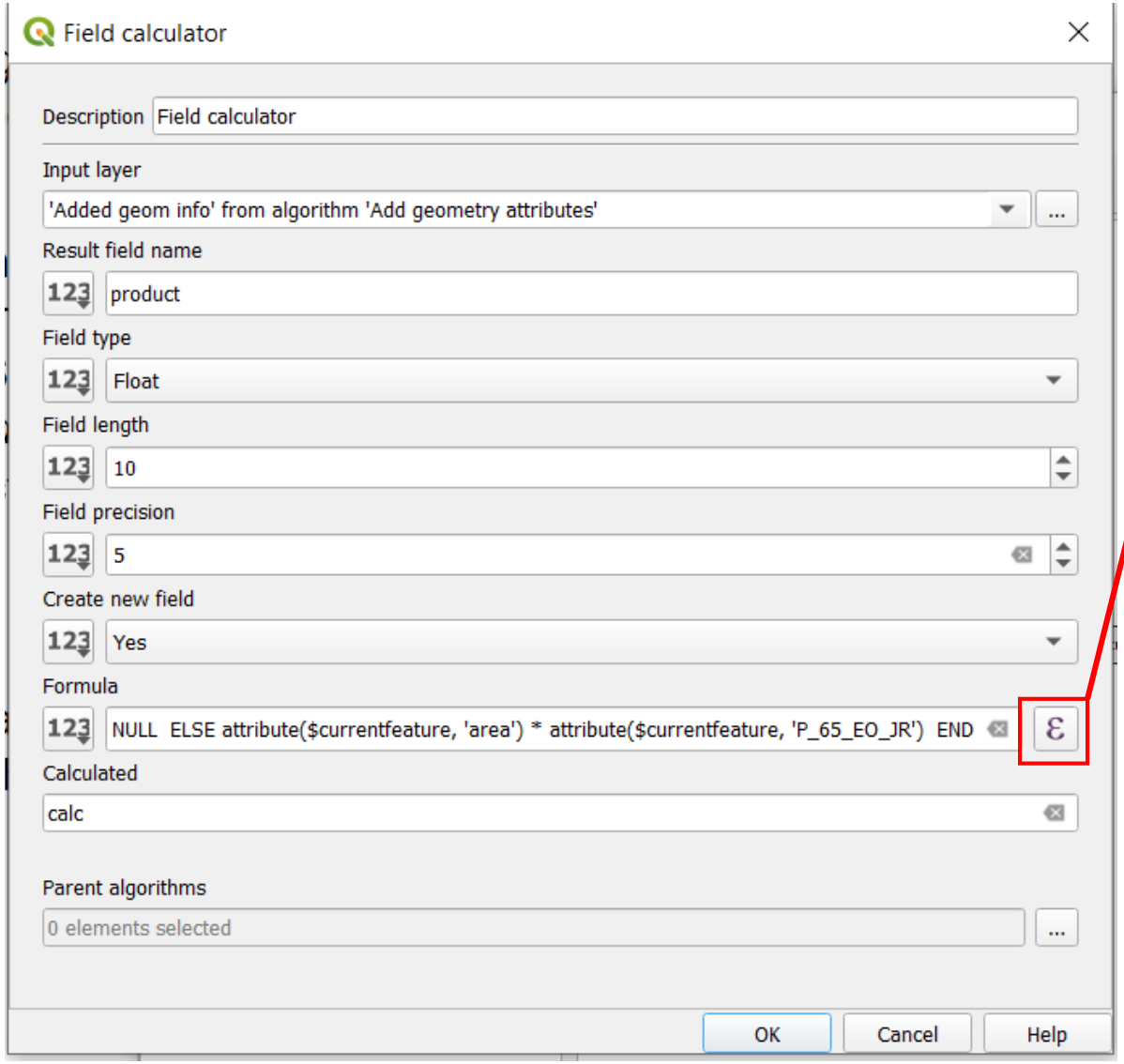
GIS contain tables (feature classes) in which:

- *rows*: *entities* (records, observations, features):
  - 'all' information about one occurrence of a feature
- columns: *attributes* (fields, data elements, variables, items (ArcGIS))
  - one type of information for all features

The *key* field is an attribute whose values uniquely identify each row

Parcel Table			
Parcel #	Address	Block	$ Value
8	501 N Hi	1	105,450
9	590 N Hi	2	89,780
36	1001 W. Main	4	101,500
75	1175 W. 1st	12	98,000

Field Calculator



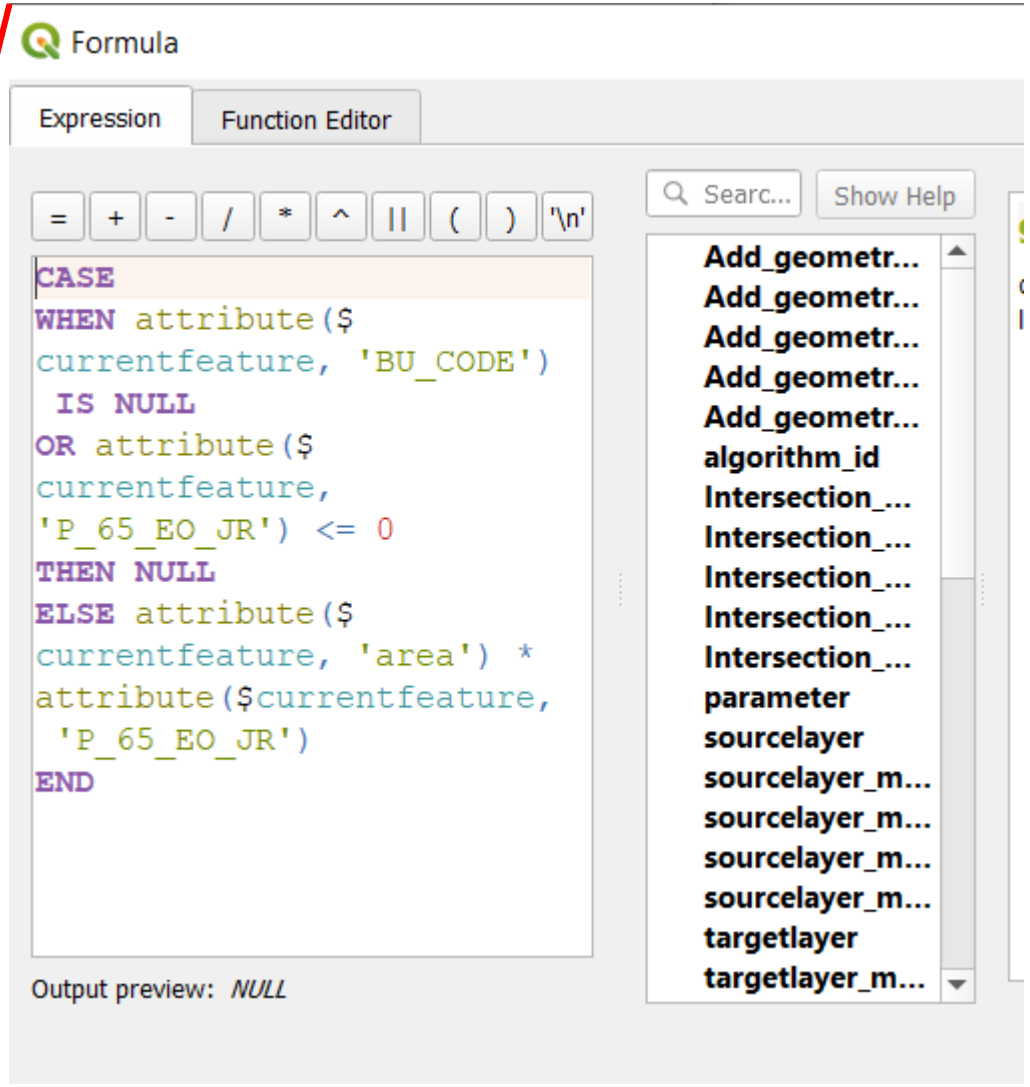
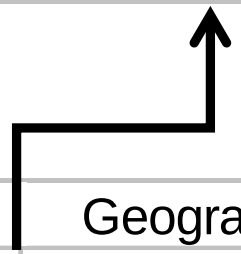


Table join

Produce map of values by district/ neighborhood

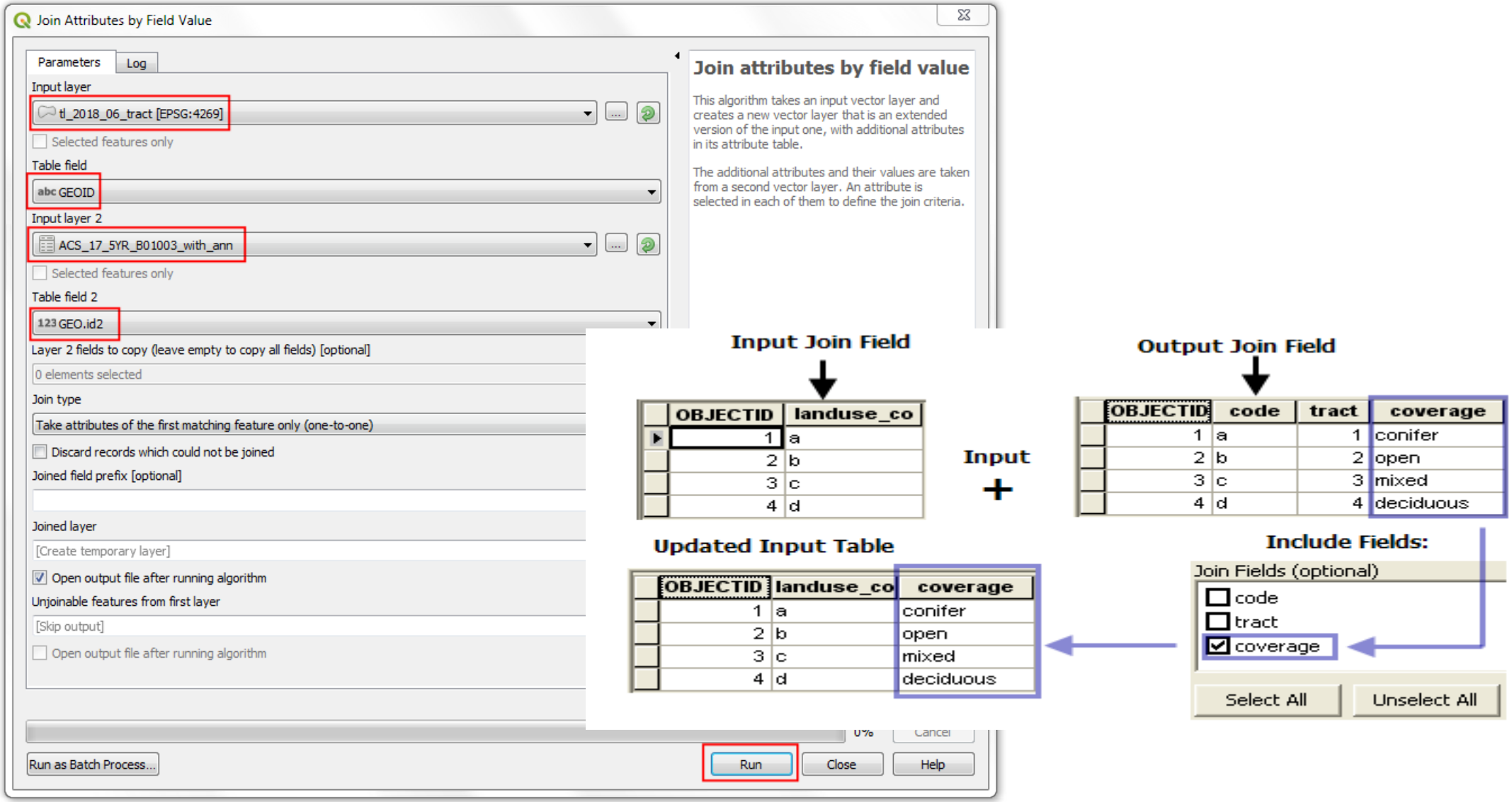
- Problem: no district code available in parcel Table
- Solution: join Parcel Table, containing values, with Geography Table, containing location codings, using Block as key field

Parcel Table			
Parcel #	Address	Block	$ Value
8	501 N Hi	1	105,450
9	590 N Hi	2	89,780
36	1001 W. Main	4	101,500
75	1175 W. 1st	12	98,000



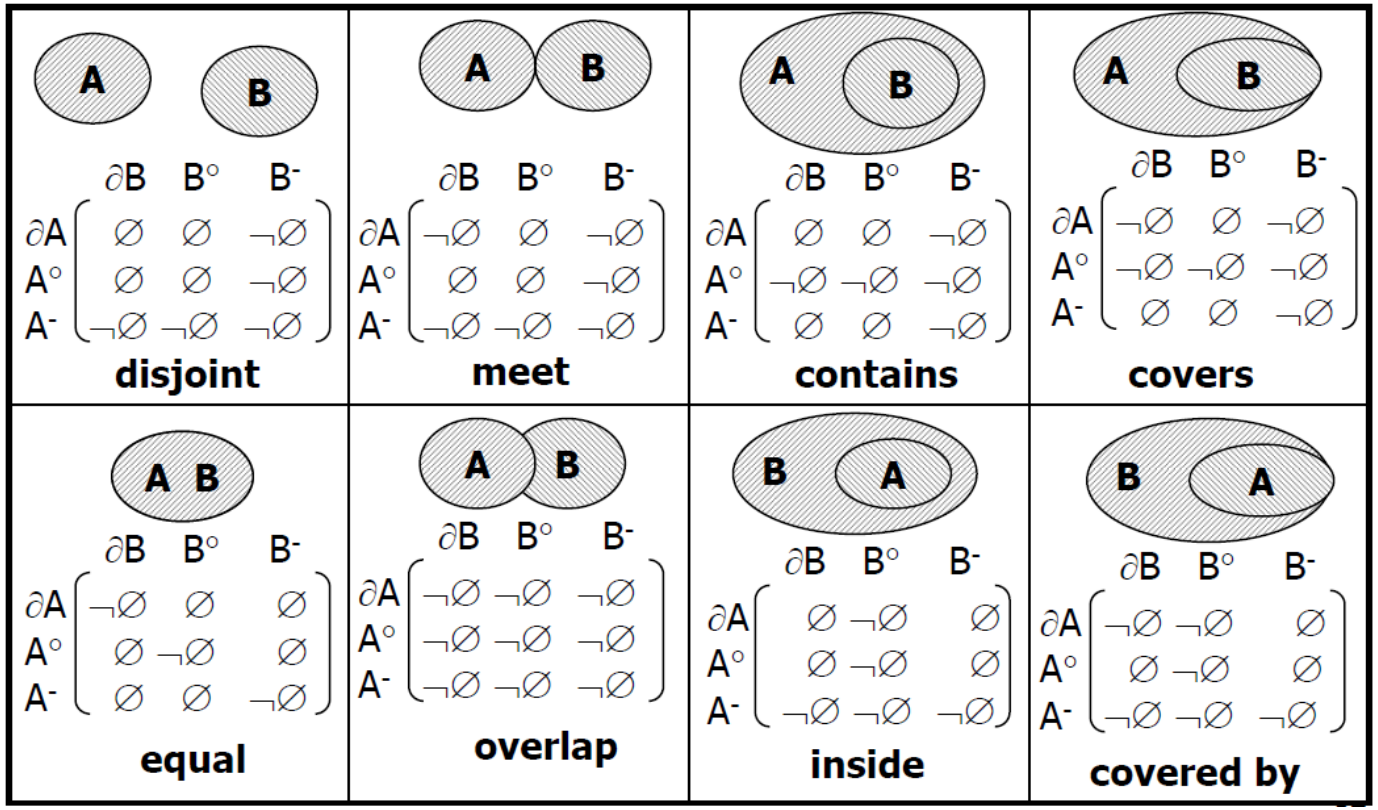
Geography Table			
Block	District	Tract	City
1	A	101	Dallas
2	B	101	Dallas
4	B	105	Dallas
12	E	202	Garland

Join Attributes by Field Value

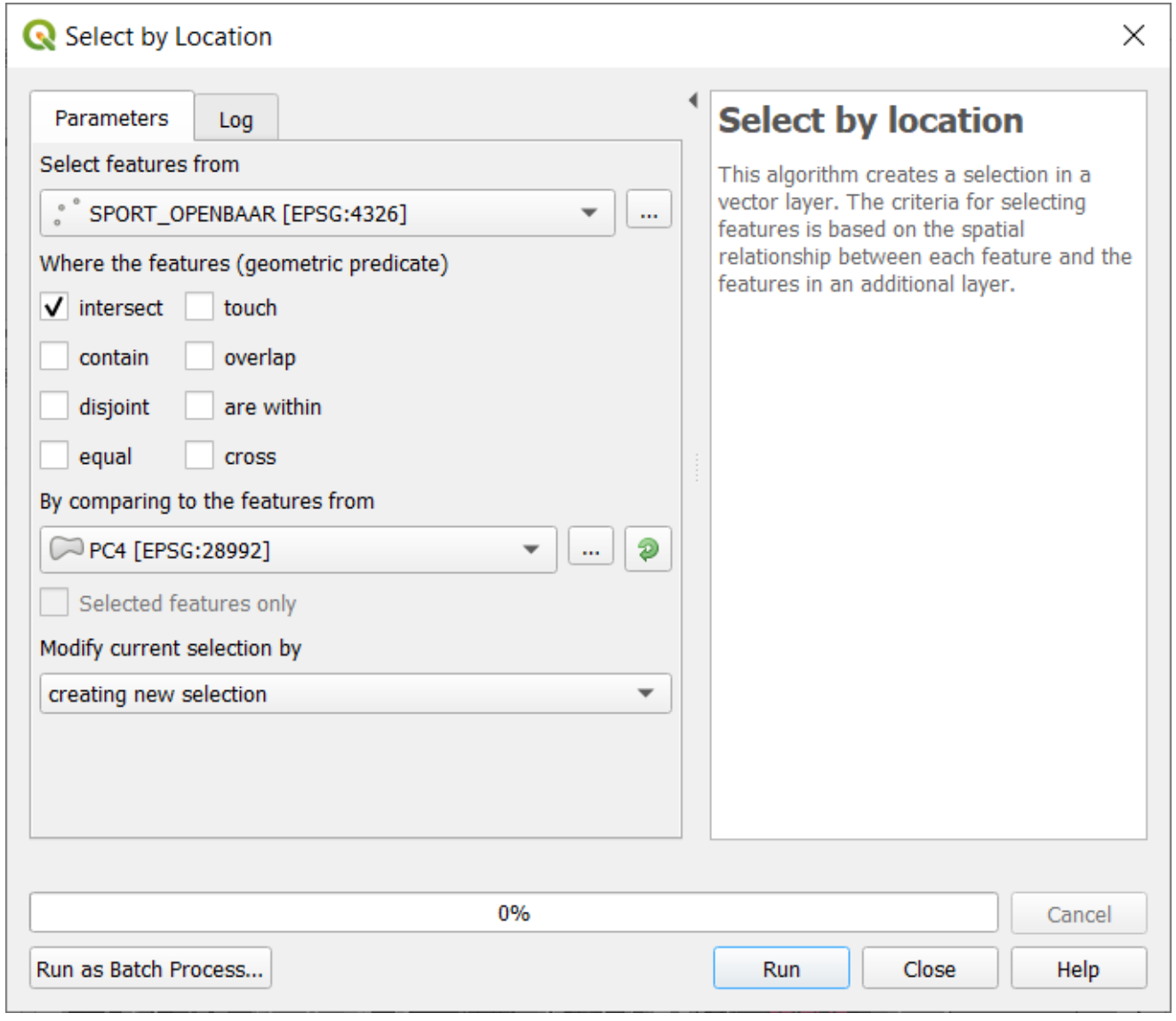


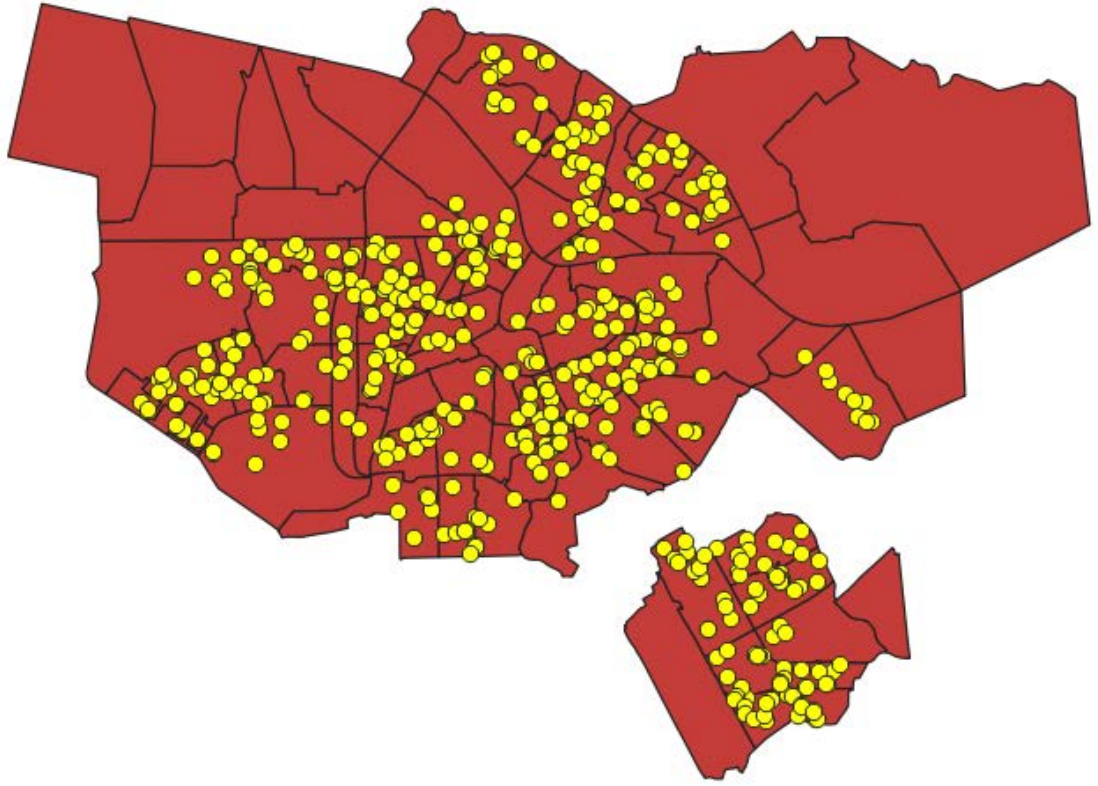
Spatial relations

- Spatial (e.g. topological) relationships can be used for joining features
- Egenhofer's 9-Intersection matrix allows to capture such relations
- Intersect = All that is not disjoint



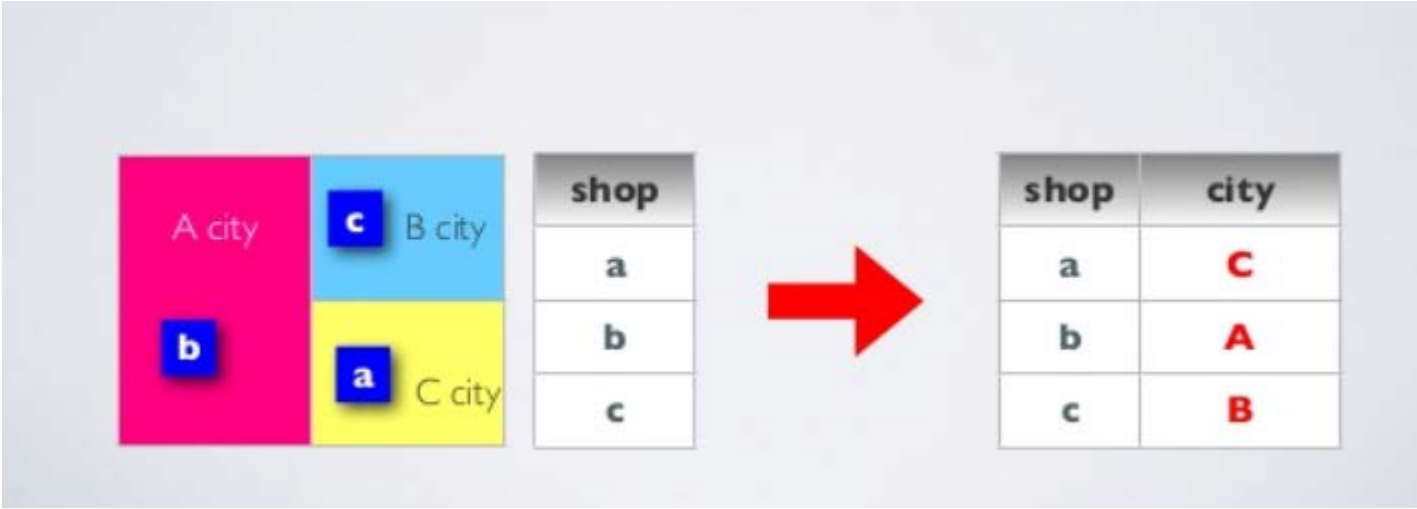
Selecting layers by location



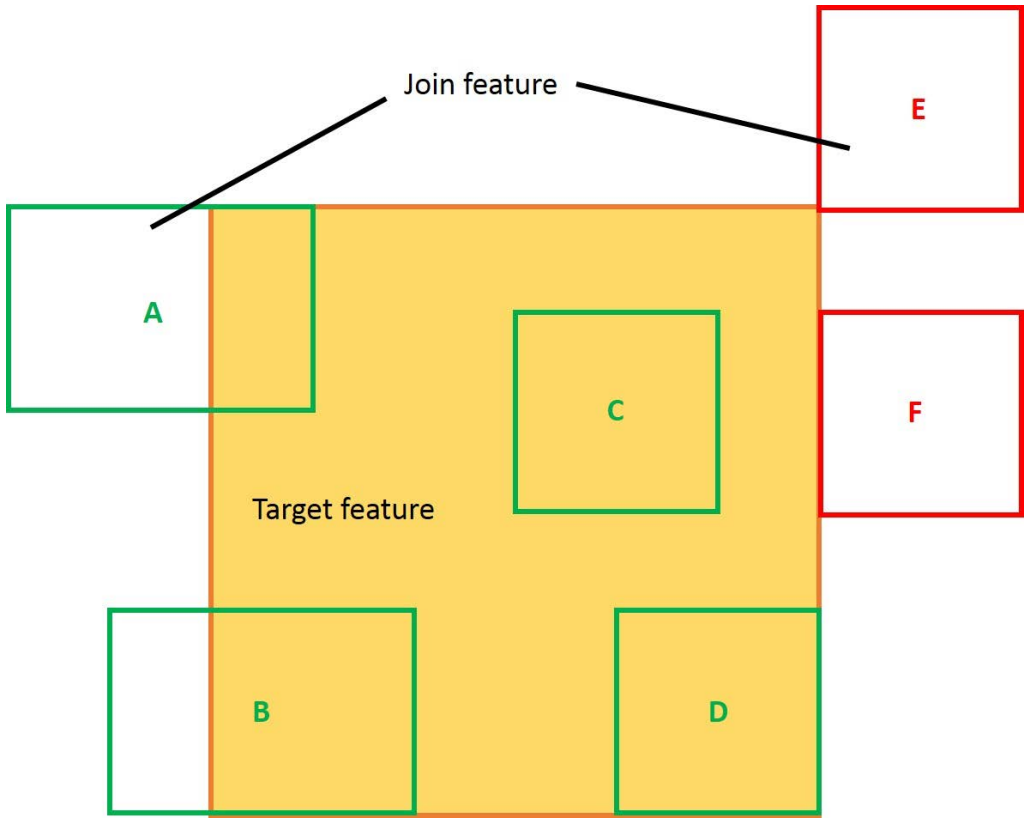


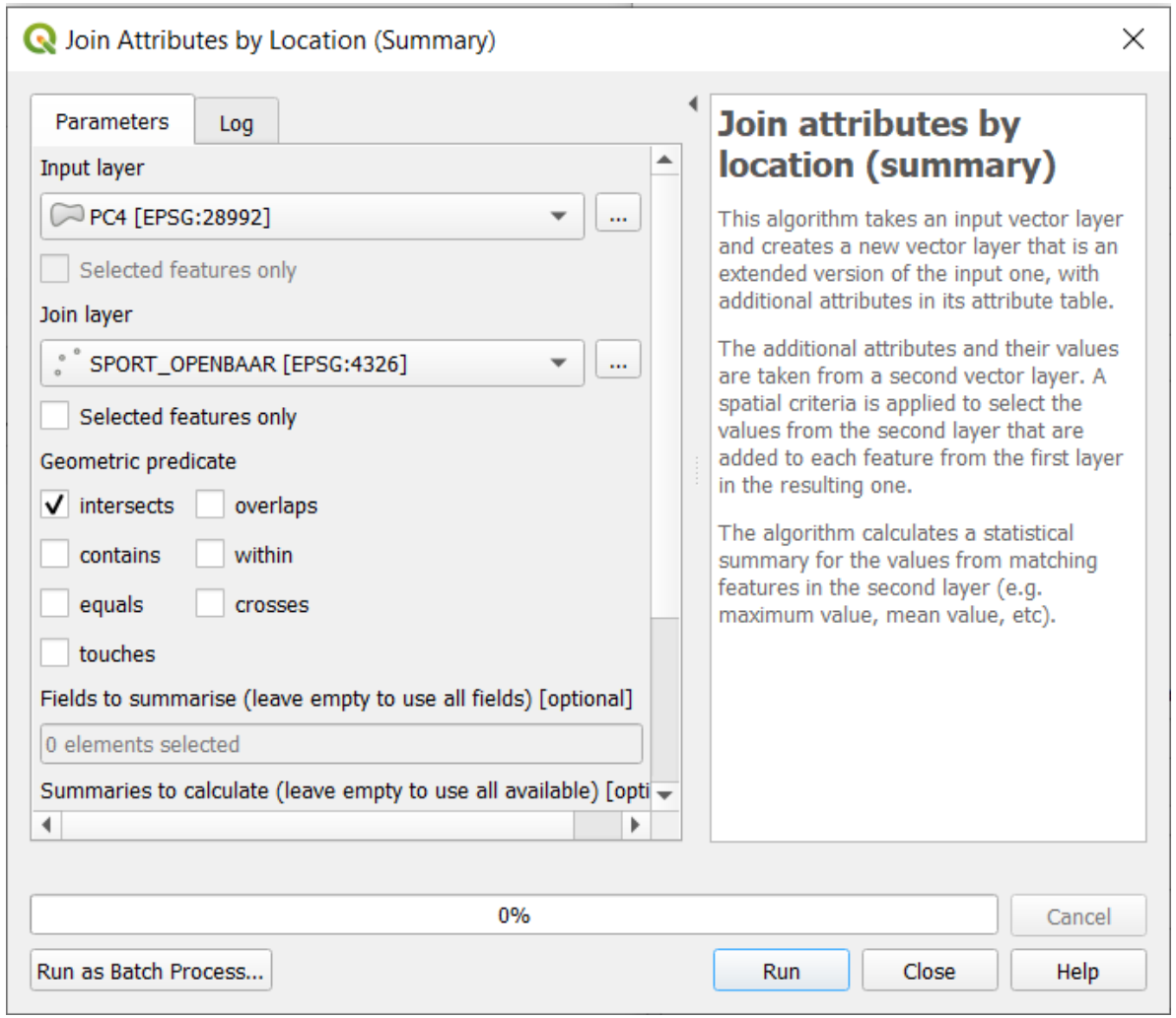
Spatial Join

- Joins attributes from one feature to another based on a spatial relationship. The target features and the joined attributes from the join features are written to the output feature class.



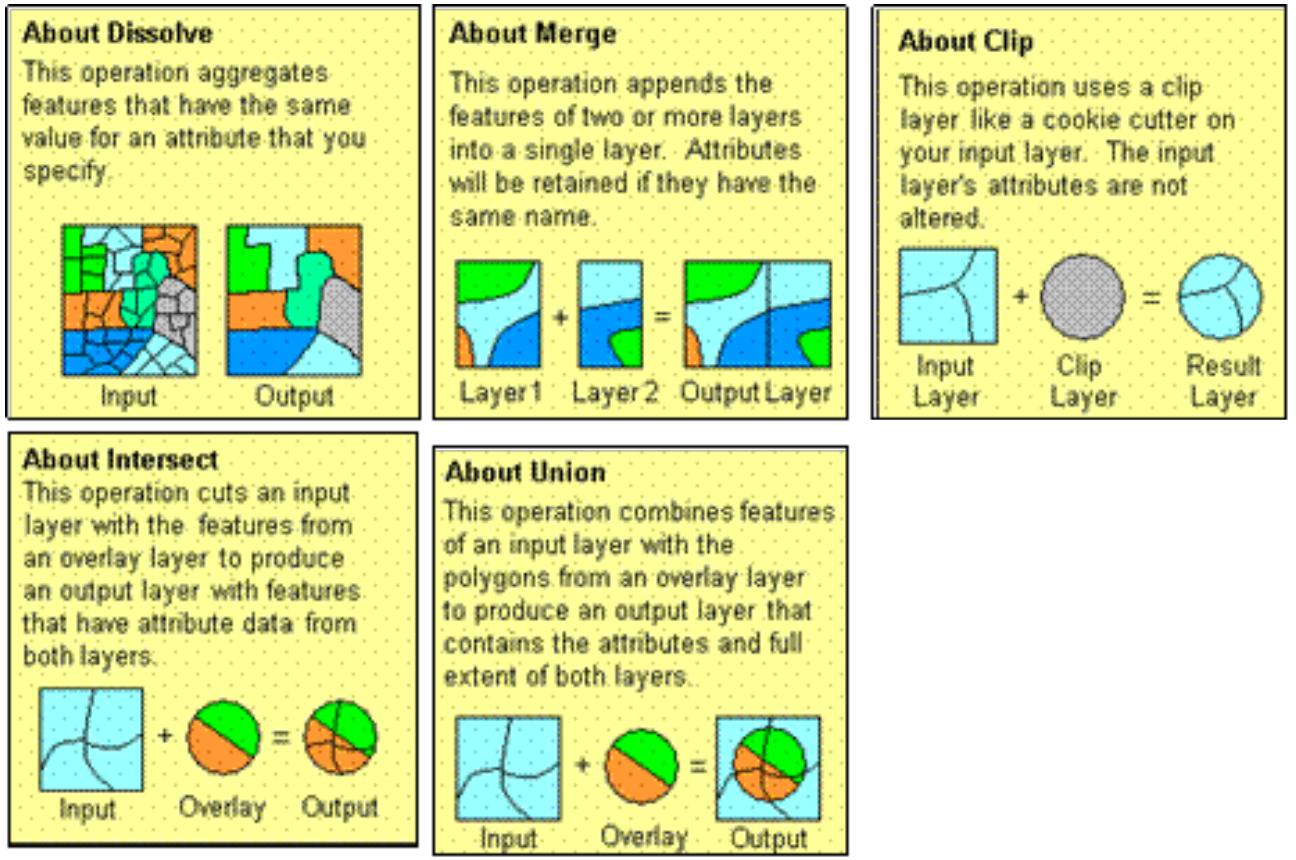
Join Attribute by Location (Summary)





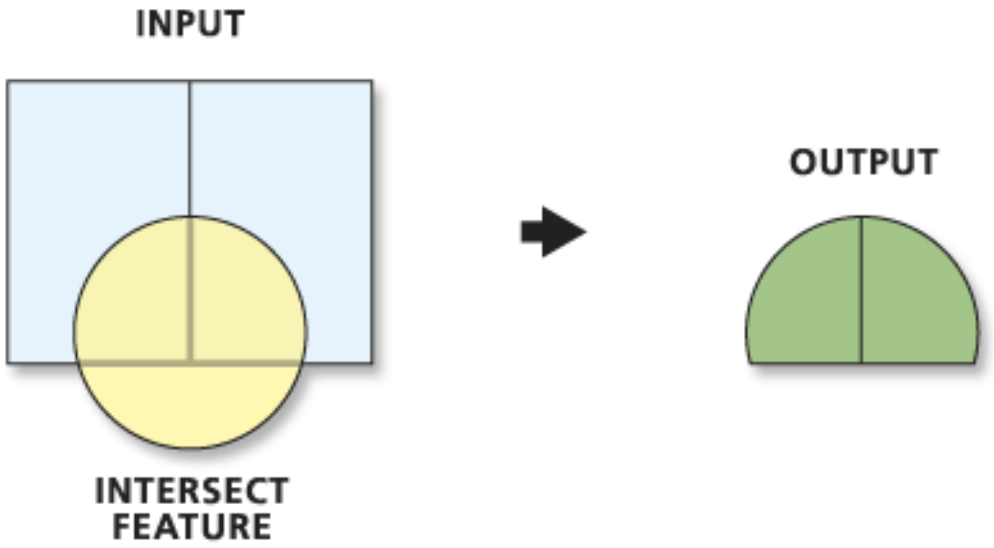
Overlay: Intersect/Clip/Union/Merge/Dissolve

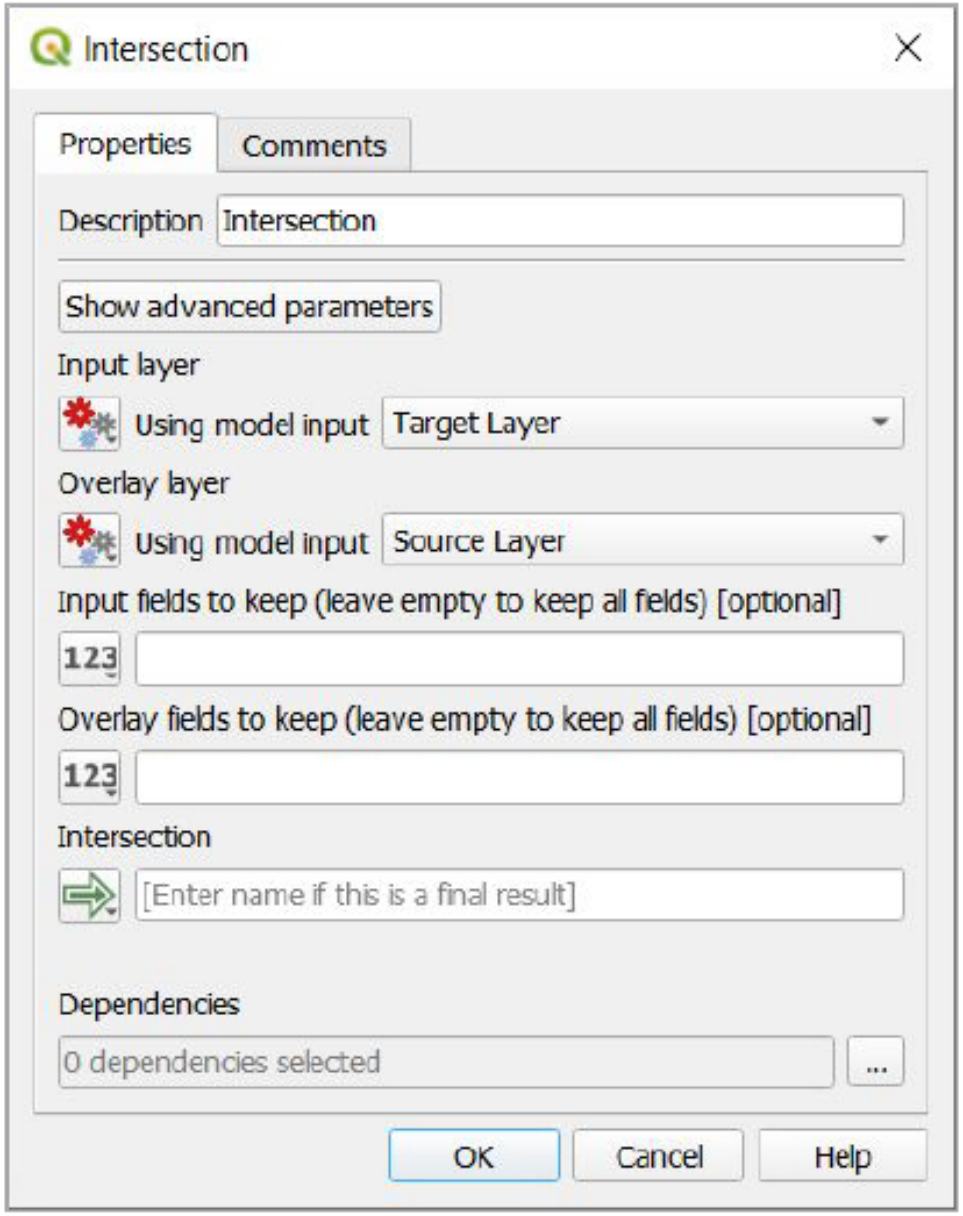
- These are point set operations (intersections or unions of point sets)
- Input are polygons or lines
- Output are new polygons or lines that were generated based on the input



Example: Intersection

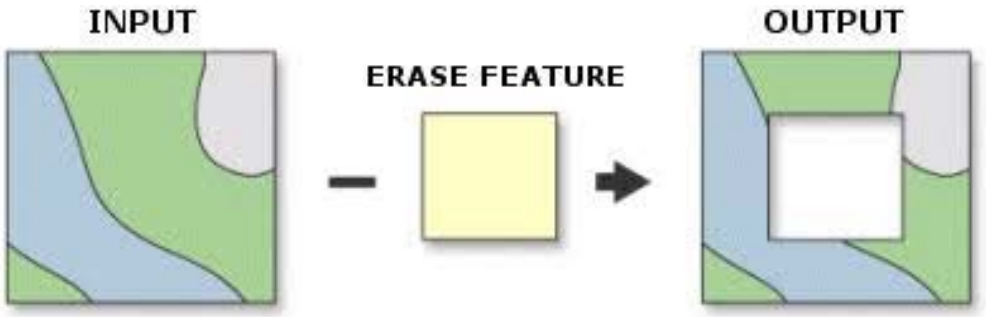
- This operation does a geometric intersection and keeps only the parts in both layers

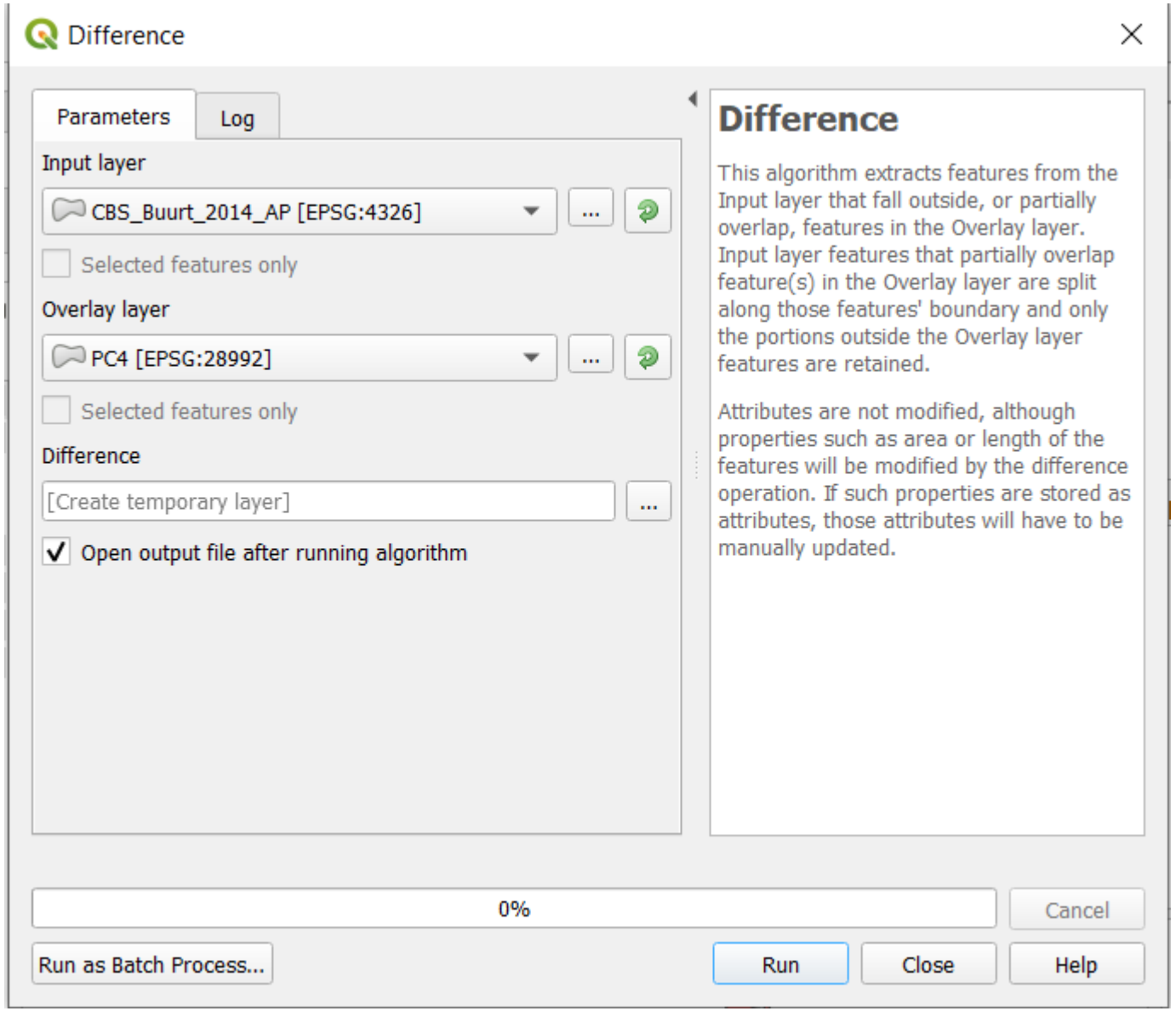




Example: Difference

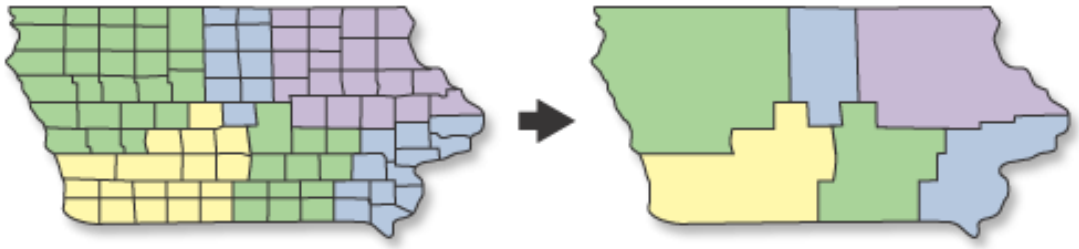
- This operation subtracts a layer from another one

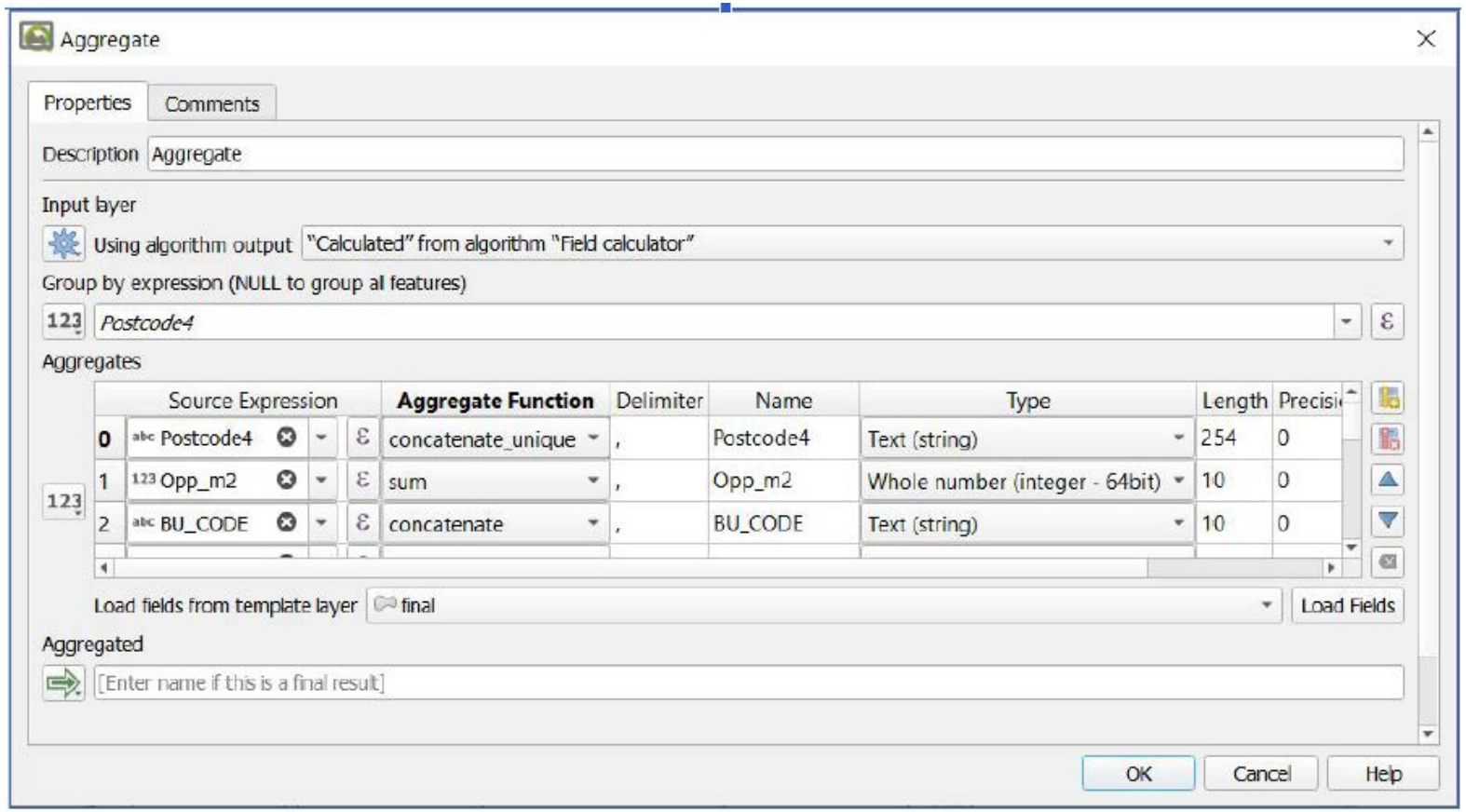




Example: Aggregate

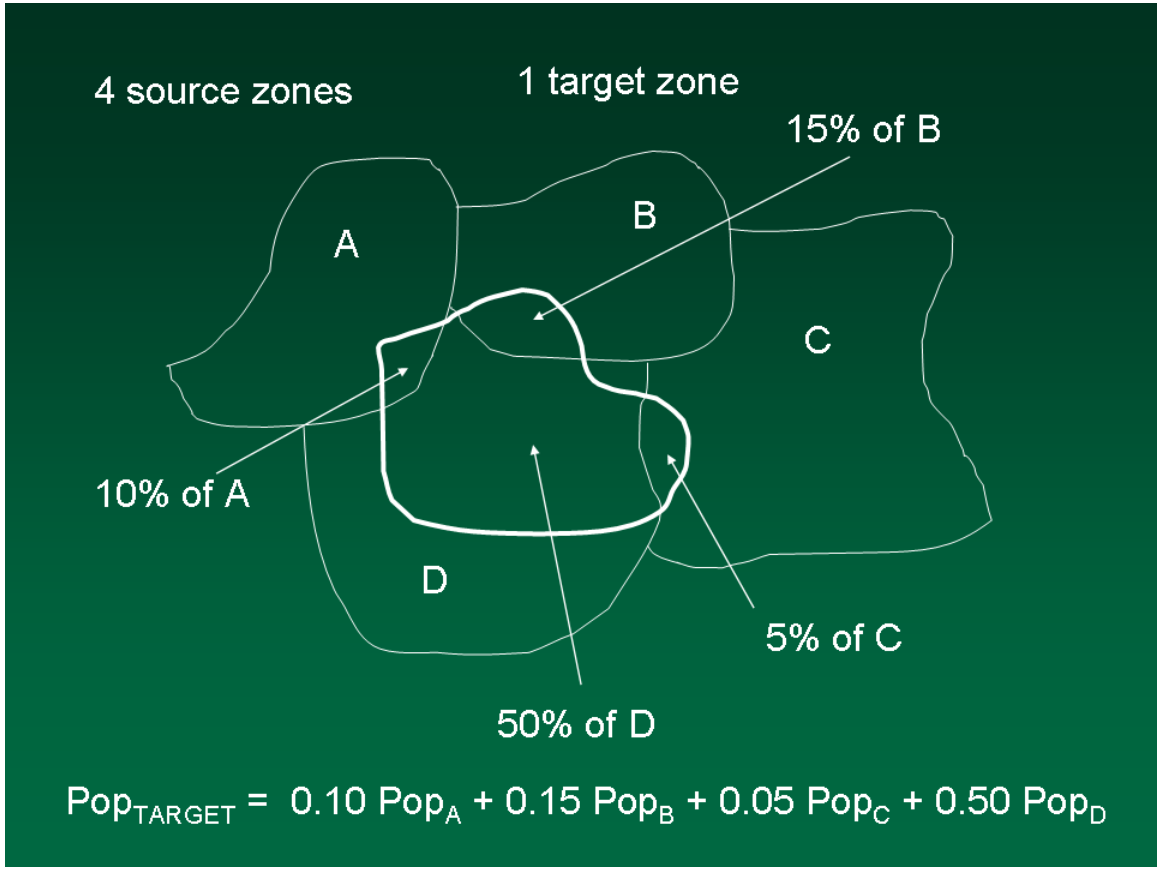
- This operation aggregates a polygon layer using some attribute and using some statistics
- Sometimes also called “Dissolve”



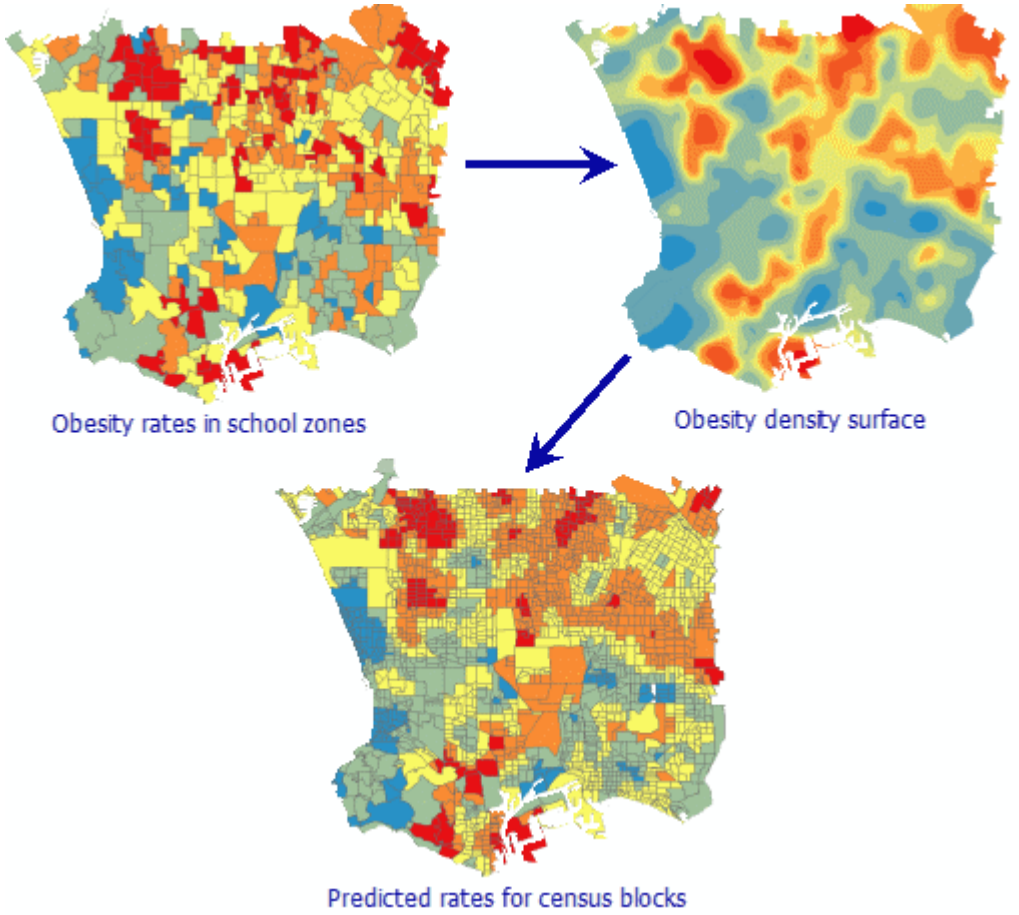


Areal Interpolation

“Simple” approach with overlay

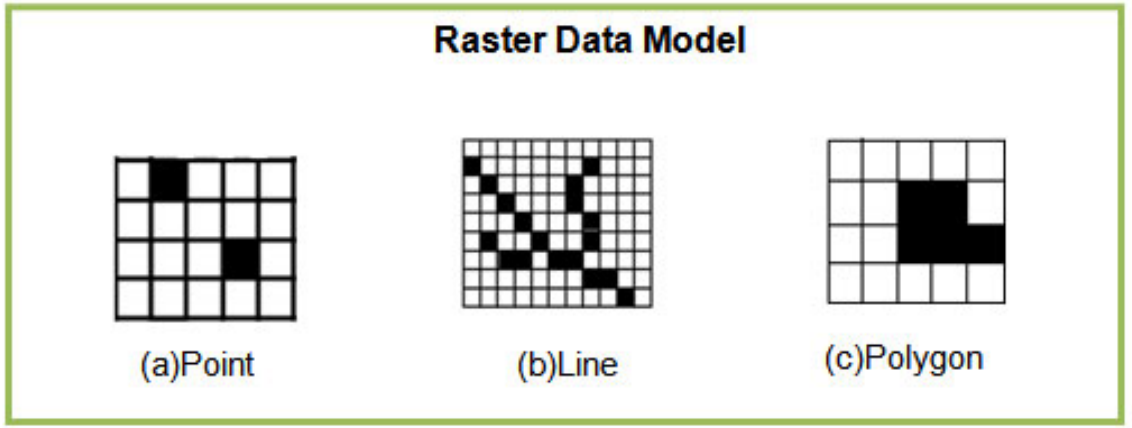


Kriging (Geostatistical Analyst)



Raster Overlay Analysis

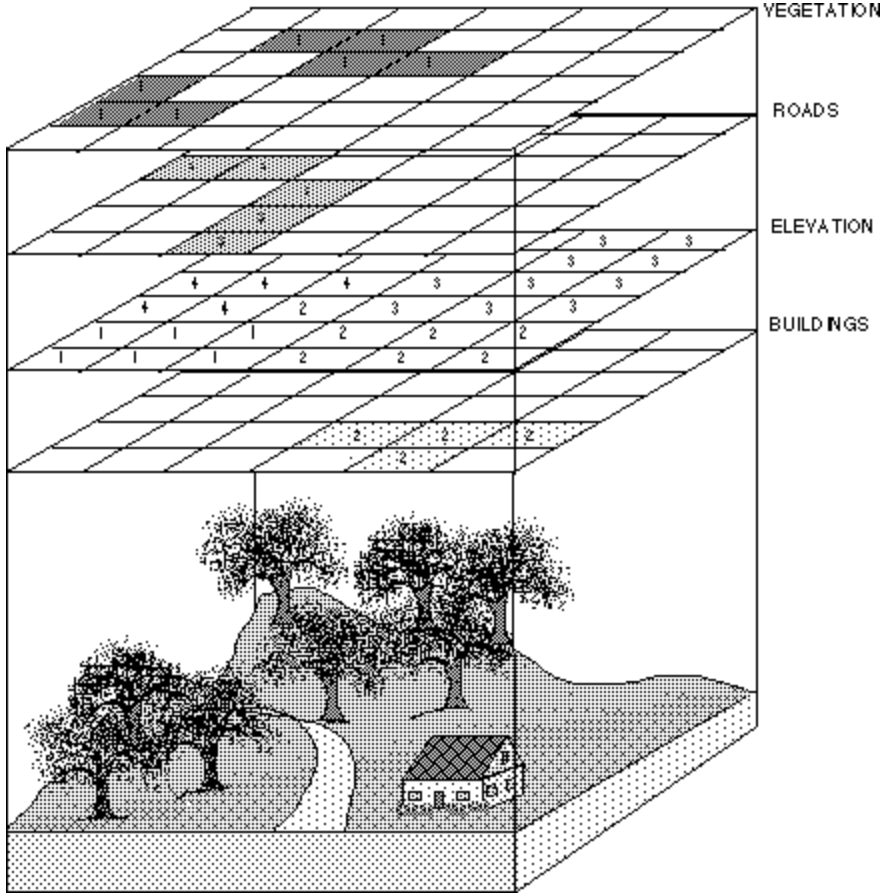
Raster data model



Array of cells or pixels (aka picture elements) which are arranged in rows and columns. Each pixel has a value in the form of integer, floating points or alphanumeric.

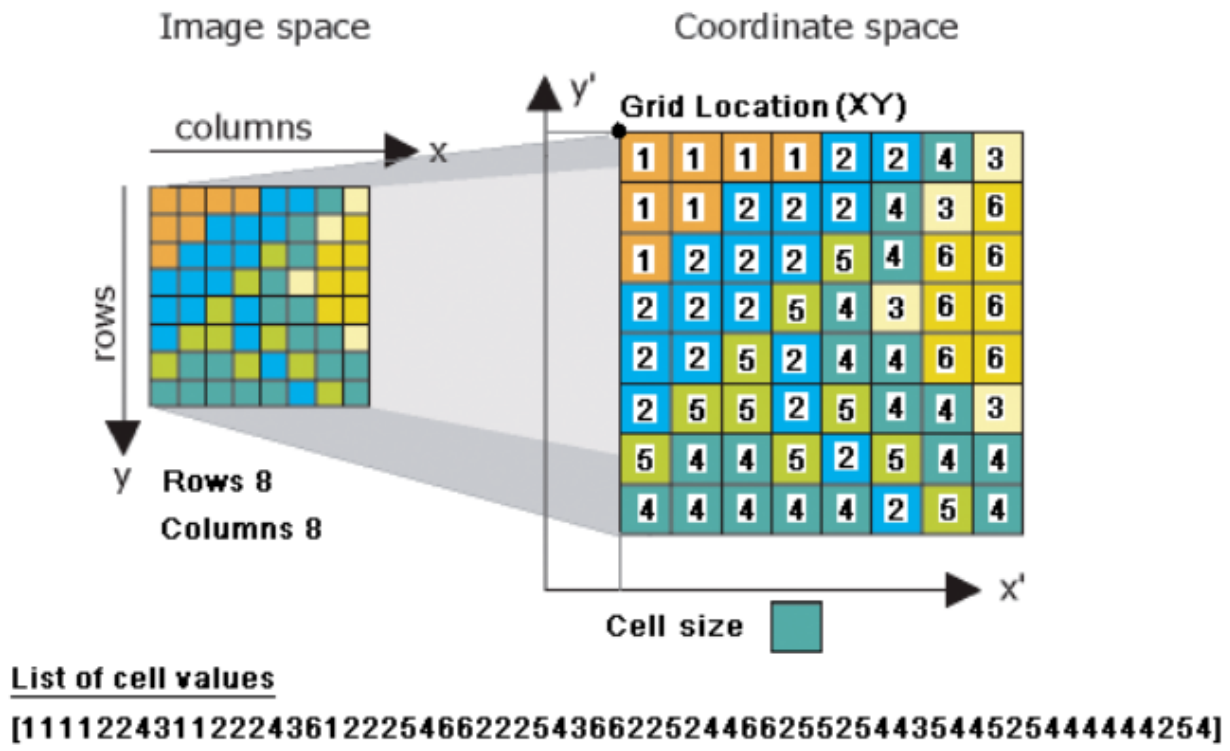
A point can be represented by a single pixel in raster model. A line is a chain of spatially connected cells with the same value.

Similarly, a water body in raster data is represented as a set of contiguous pixels having same value that represents a homogeneous area.



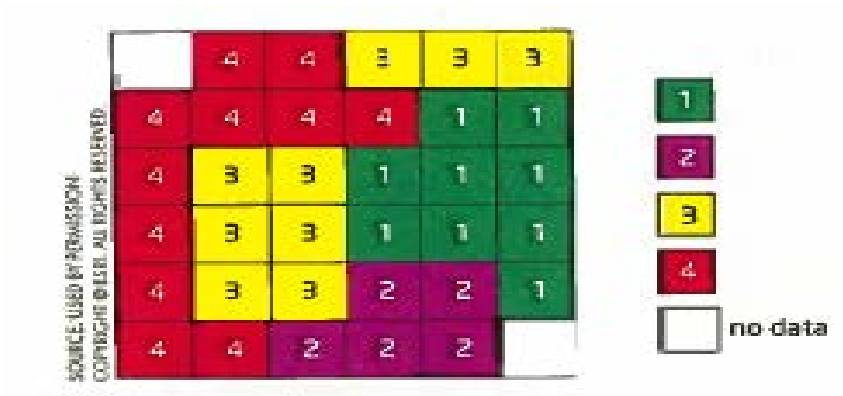
Raster cells: more than pixels

- Rows / columns of pixels
- Cell coordinates and values
- Possible meaning of cell value?
  - feature identifier
  - qualitative characteristic
  - quantitative characteristic
  - representation of zone



Raster zones, regions and NoData/Null

- Zone: refers to the set of cells sharing a certain value (connected or disconnected)
- Region: zone with connected cells
- NoData/Null <> 0
- Associated table (in case of integers) (value,count)



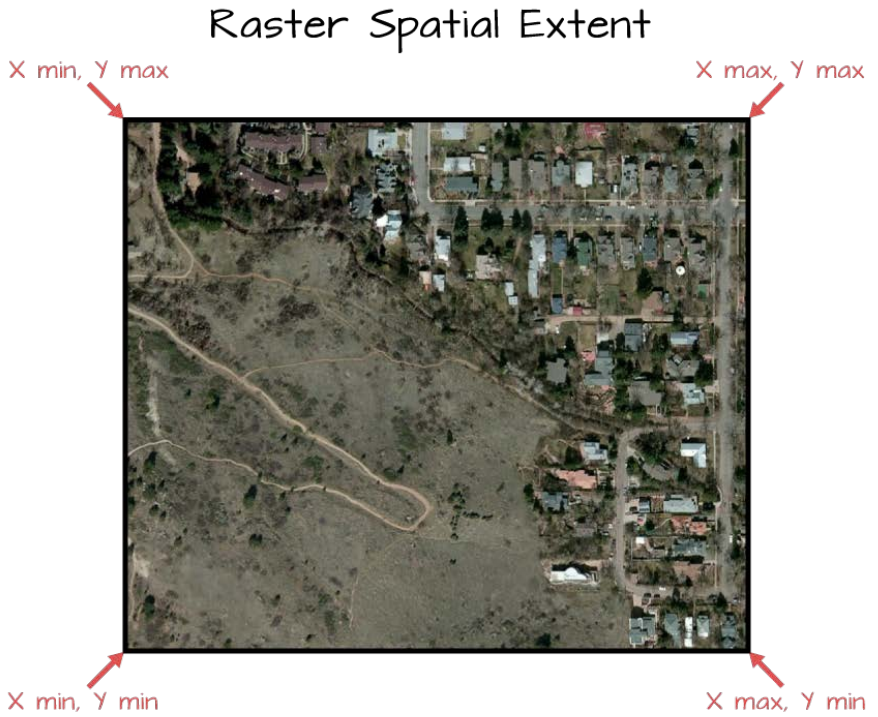
Cell size and extent

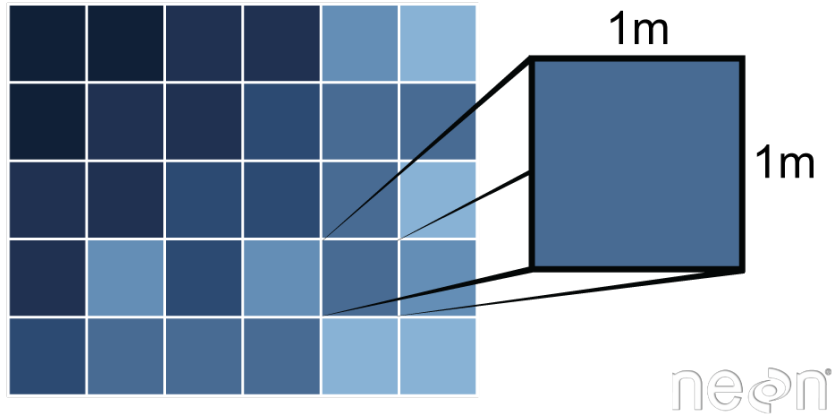
How to decide on resolution (cell size)?

- Resolution of input data
- The output needed for your analysis
- Response time (processing speed)
- Kind of application / analysis

Raster resolution increases as the size of the cell decreases

Raster extent: Same as display or layer?





Map Algebra

- Introduced by Dana **Tomlin** and Joseph **Berry** (Tomlin 1990)
- **Cell-by-cell** combination of raster data layers (addition, subtraction, multipl.,…)
- Simple **operations** on numbers stored as values at **raster** cell locations
- Output grids with results at the cell locations **corresponding to input cells**

Map Algebra: Basic elements

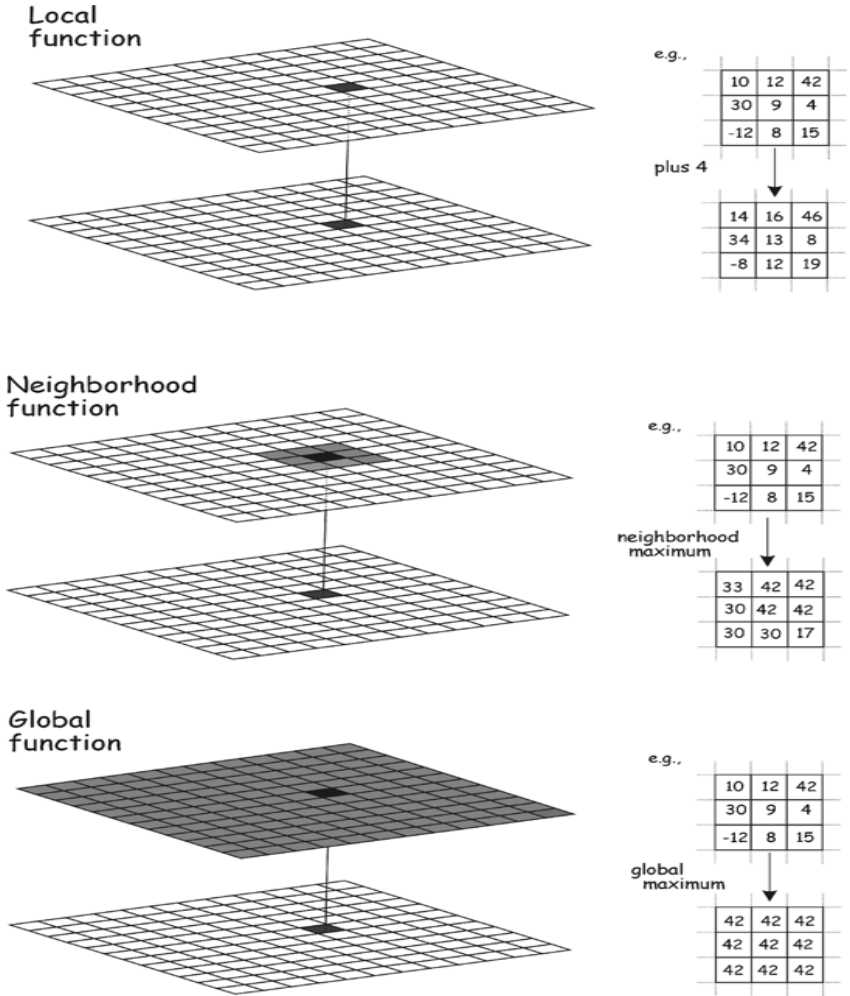
Building blocks for Map Algebra language are:

- **Objects** - datasets, layers, values (as inputs or storage location)
- **Operators** (+, -, *, …)
- **Functions** (loc,foc,zon,glob)
- **Actions** – Result of applying functions with operators to objects
- **Qualifiers on the actions** – parameters determining the conduction of a function

Map Algebra: Functions

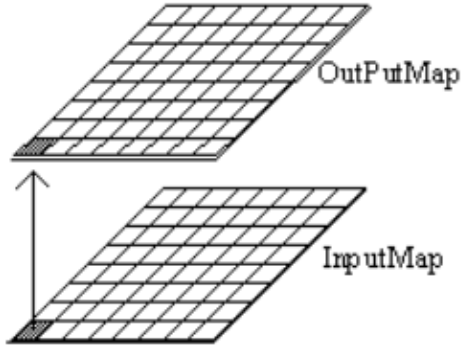
Higher-order GIS operation (why?)

- Important building blocks for modeling **Parameter-dependent**
- **Local**: cell-by-cell
- **Neighborhood** (**Focal**): moving neighborhood
- **Zonal**: within homogeneous zones
- **Global**: incorporation of the full dataset

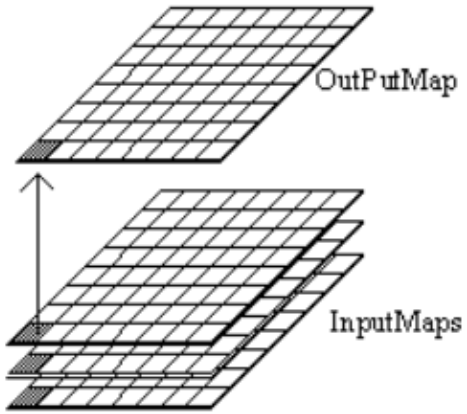


Example: Local Map algebra function

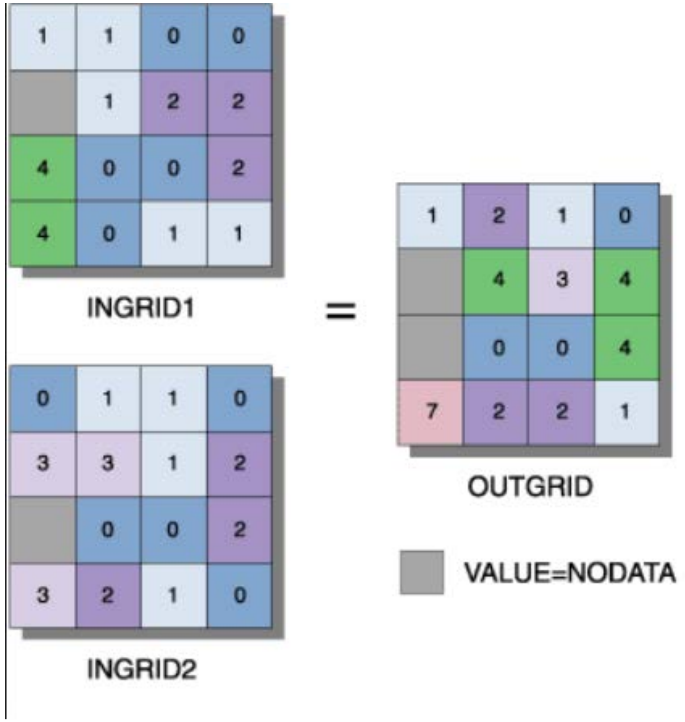
- Local functions: on equivalent cells across raster layers
- Quiz: What arithmetic operator is used in this local function example?
- local sum



a) Singlevalues Associated with Individual Locations

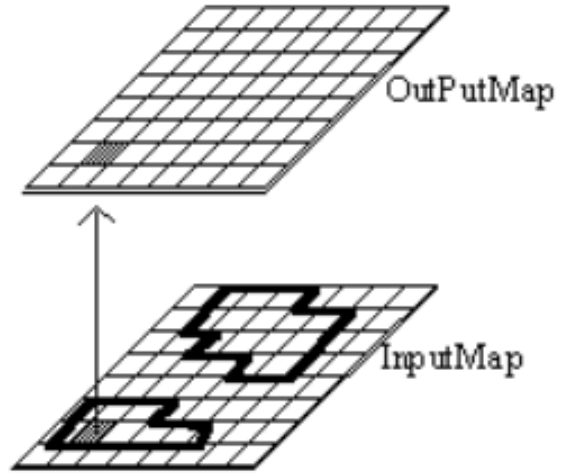


b) Multiplevalues Associated with Individual Locations

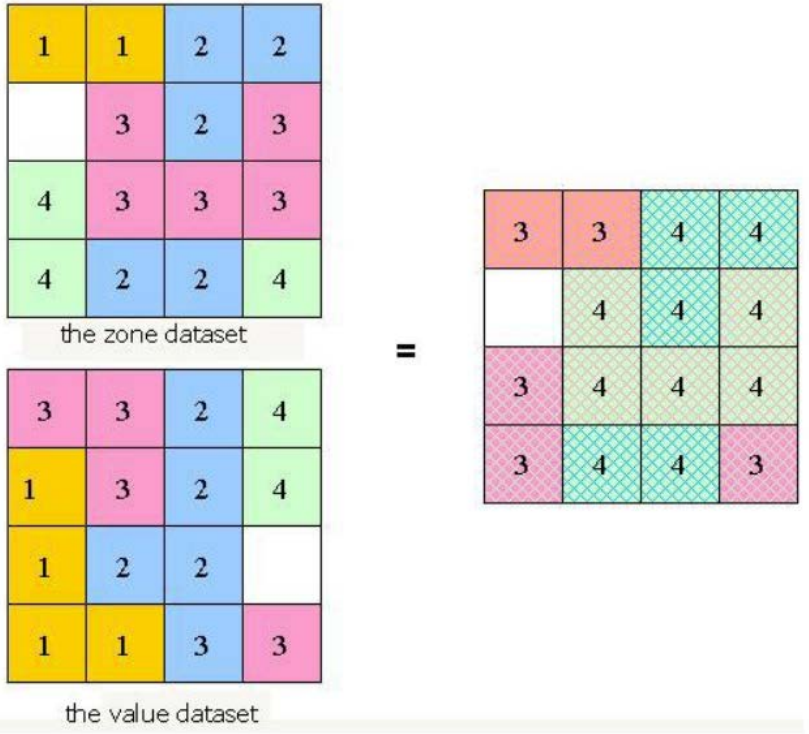


Example: Zonal Map algebra function

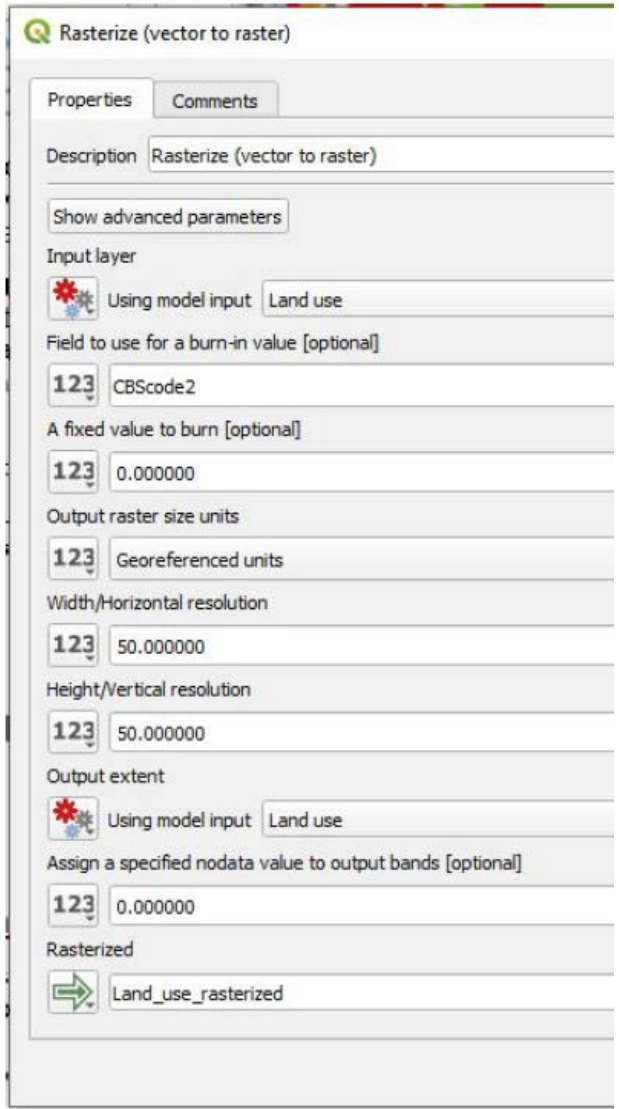
- Zonal functions: on cells within specified zones (zones defined by cell values of zone raster)
- Quiz: What operator is used in this zonal function example?
- Zonal maximum

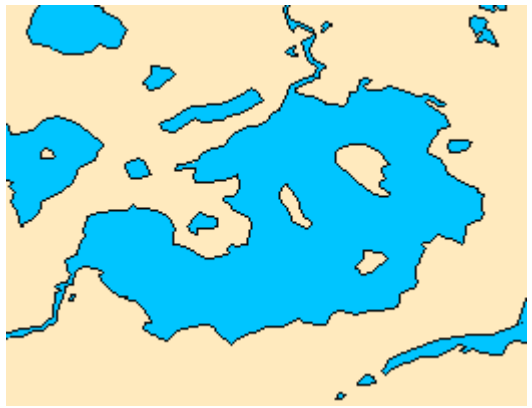


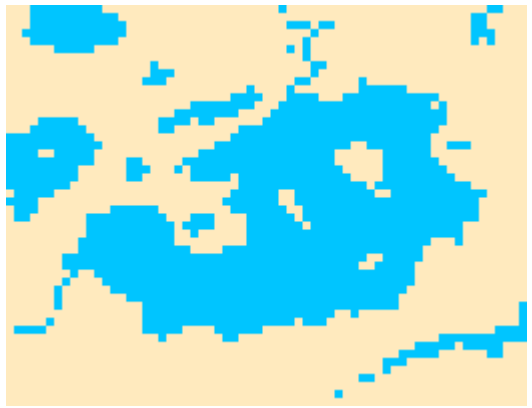
a) Entire Zones or Regions



Rasterize/vector to raster (Local Map Algebra)







Reclassify (Local Map Algebra)

a)

Input

1	3	1	1
0	N	2	-1
1	2	5	0
0	1	N	N

Reclass by table

in	out
0	a
1	x
2	b
3	f
4	c
5	s

=

Output

x	f	x	x
a	N	b	N
x	b	s	a
a	x	N	N

b)

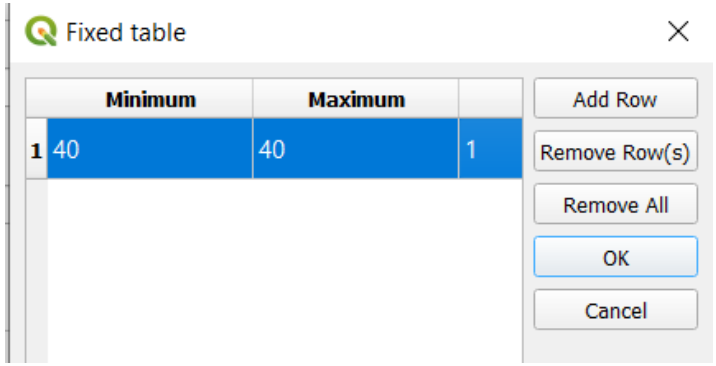
1	3	1	1
0	N	2	-1
1	2	5	0
0	1	N	N

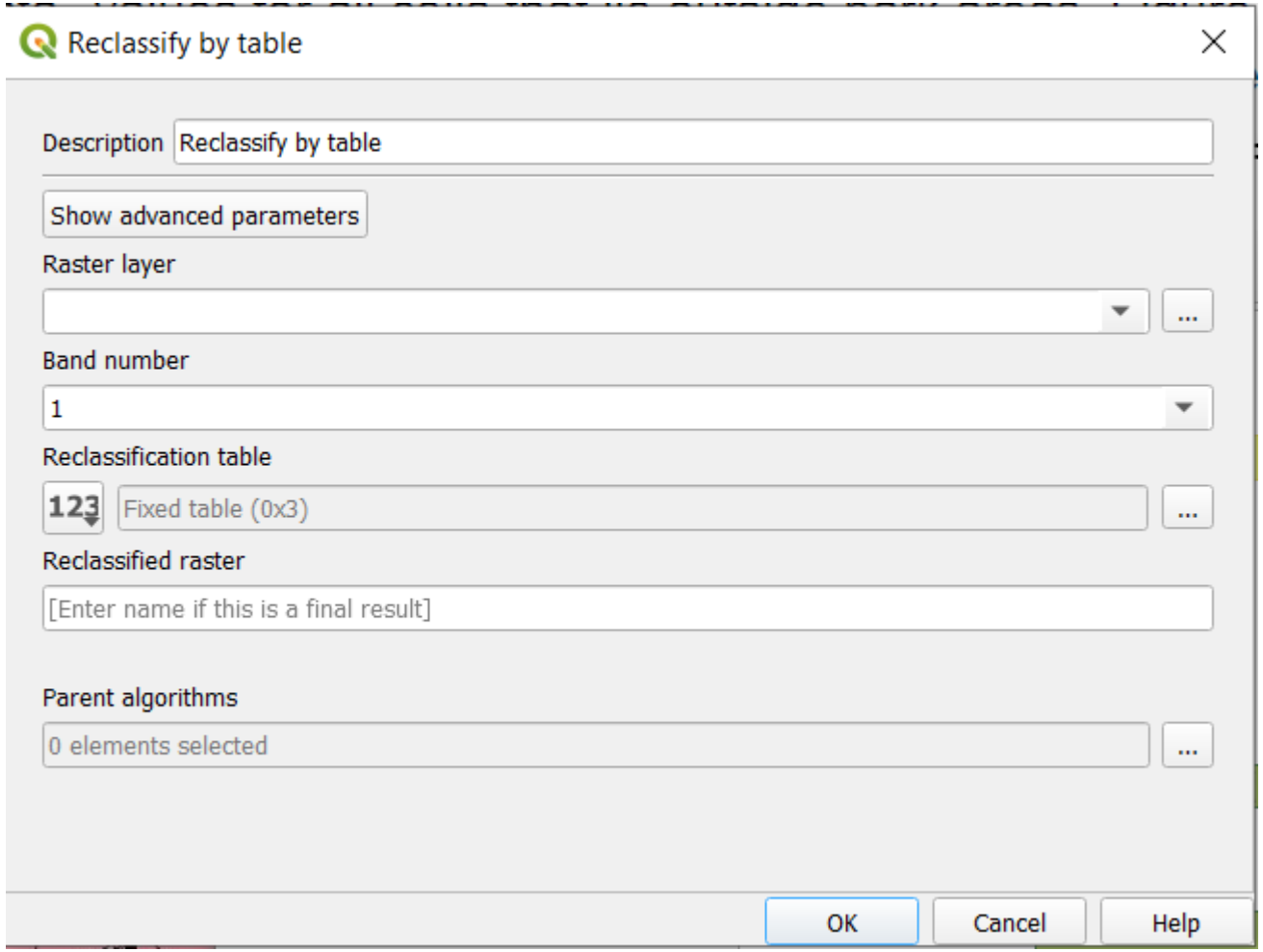
Reclass by ranges

in range	out
0 to 1.5	a
1.5 to 3.5	b
3.5 to 10	c
N	d

=

a	b	a	a
a	d	b	N
a	b	c	a
a	b	d	d





Raster Calculator (Local Map Algebra)

Raster Calculator

Parameters | Log

Expression

Layers

landuse@1

Operators

+	*	cos	sin	log10	AND
-	/	acos	asin	ln	OR
^	sqrt	tan	atan	(	)
<	>	=	!=	<=	>=

Expression

"landuse@1" + "landuse@1"

Predefined expressions

Raster calculator

This algorithm allows performing algebraic operations using raster layers.

The resulting layer will have its values computed according to an expression. The expression can contain numerical values, operators and references to any of the layers in the current project. The following functions are also supported:

- sin(), cos(), tan(), atan2(), ln(), log10()

The extent, cell size, and output CRS can be defined by the user. If the extent is not specified, the minimum extent that covers selected reference layer(s) will be used. If the cell size is not specified, the minimum cell size of selected reference layer(s) will be used. If the output CRS is not specified, the CRS of the first reference layer will be used.

The cell size is assumed to be the same

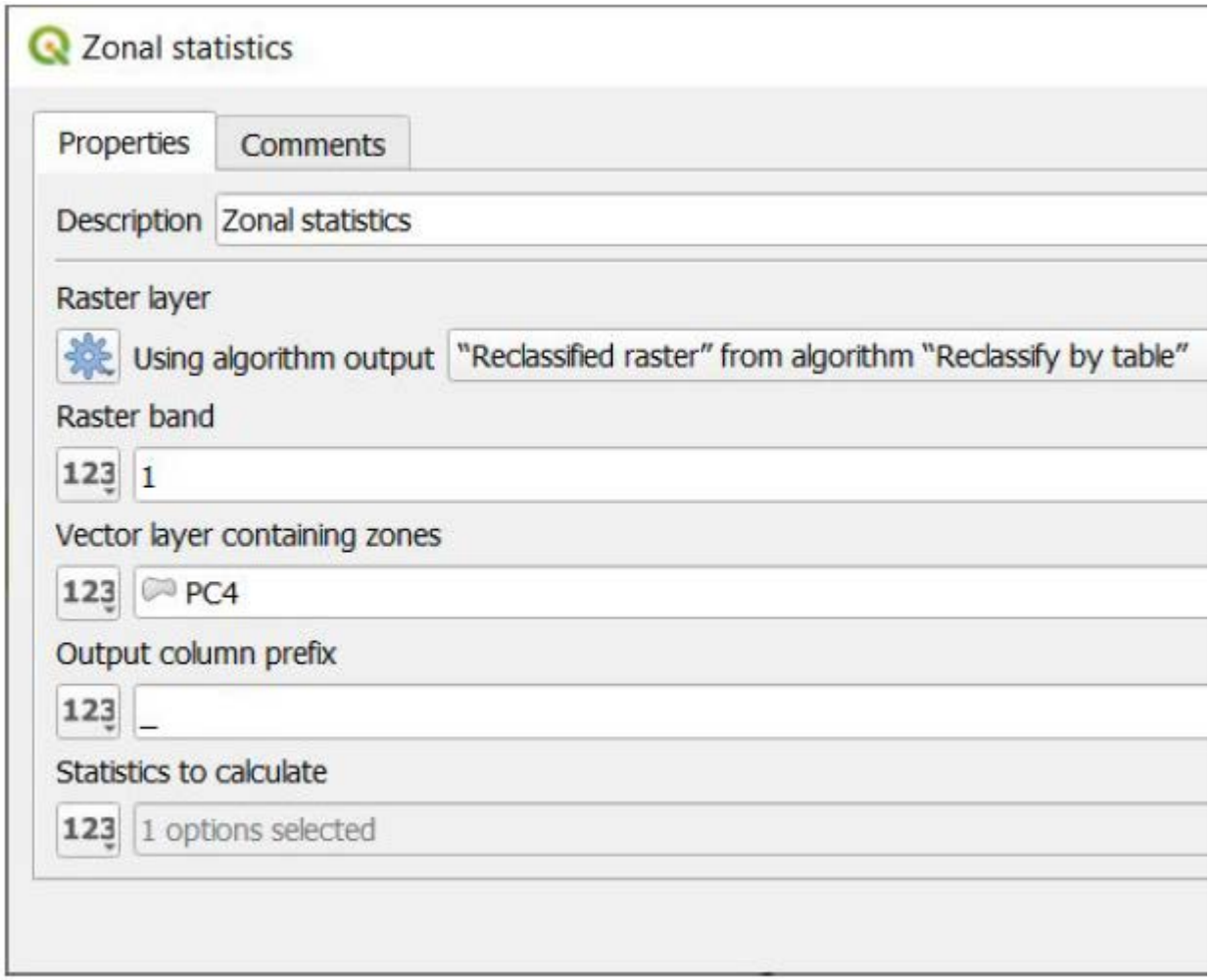
0%

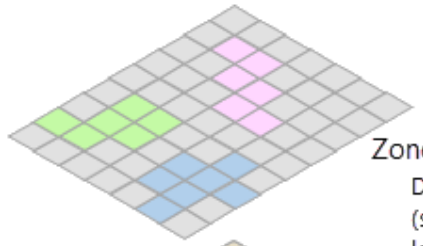
Cancel

Run as Batch Process...

Run | Close | Help

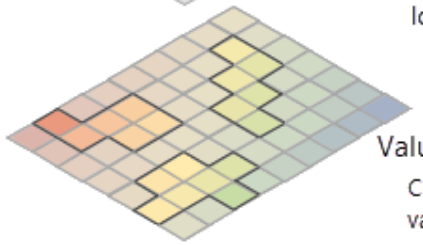
Zonal Statistics





Zone Raster

Defines the zones (shapes, values and locations).



Value raster

Contains the input values used in calculating the output for each zone.

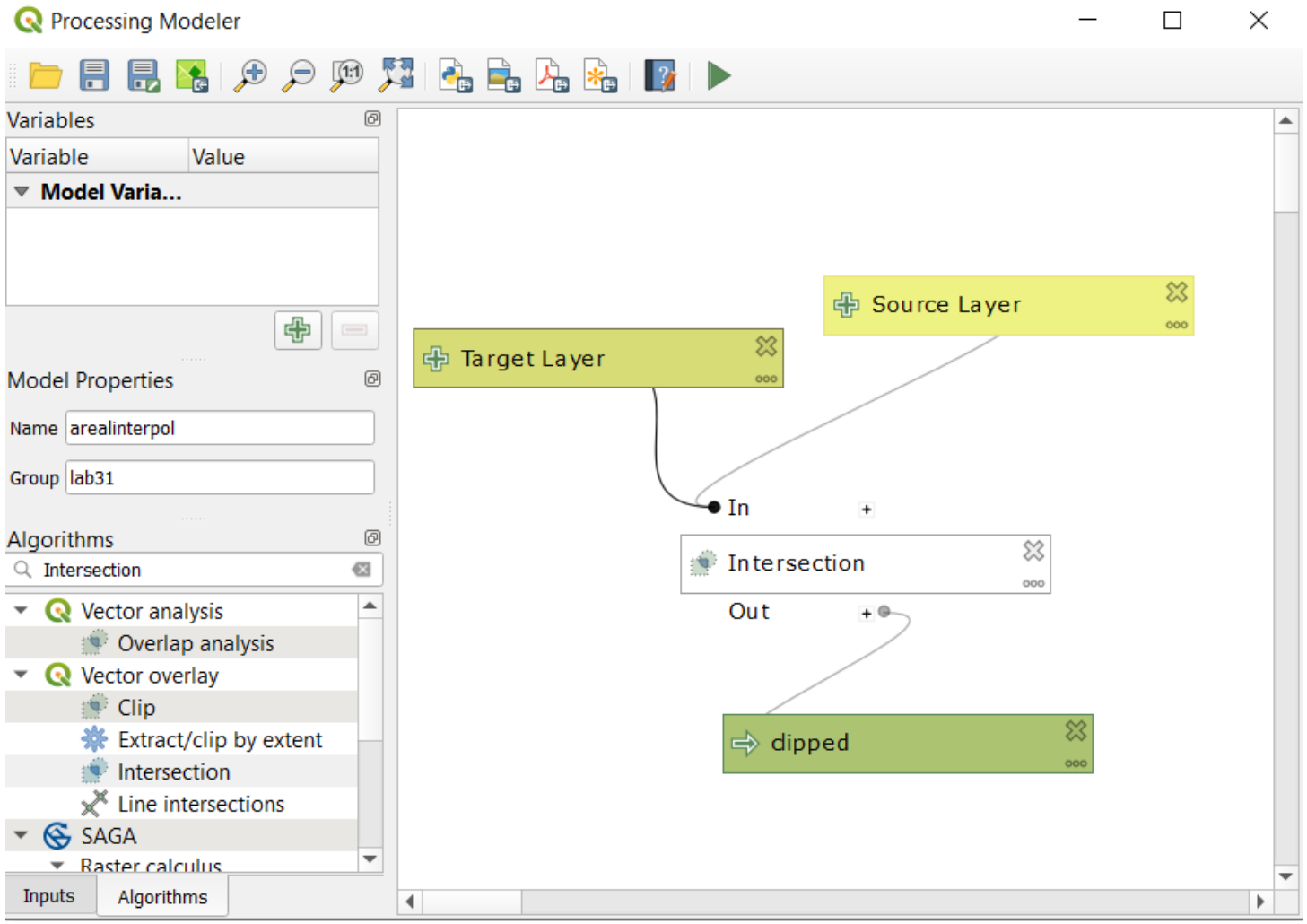
Note: Zone Raster can also be a Polygon layer!

Following values calculated for each zone:

- minimum
- maximum
- sum
- count
- mean
- standard deviation
- number of unique values
- range
- variance

Processing models (visual programming)

- Use Processing Modeller to save/rerun processing workflows and export them into Python



Questions?
(Q&A session)

References

- Chrisman (2002): Exploring Geographic Information systems, 2nd edition, Chapter 4 “Attribute based operations” (105-118)
- Chrisman (2002): Exploring Geographic Information systems, 2nd edition, Chapter 5 “Overlay: Integration of disparate sources” (119-152)
- Tomlin, C. D. (1990). Geographic information systems and cartographic modelling. New Jersey, US: Prentice-Hall.
- Egenhofer, M. J., & Franzosa, R. D. (1991). Point-set topological spatial relations. International Journal of Geographical Information System, 5(2), 161-174.