Spatial Tools in Water Resource Management

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2. Spatial Analysis in GIS

Course Introduction: People

Lecture	Contact person
Introduction to GIS	Susan Steele-Dunne
Spatial Analysis in GIS	Susan Steele-Dunne & Olivier Hoes
Watershed Delineation	Susan Steele-Dunne
Introduction to Remote Sensing & Visible RS	Nick van de Giesen
Thermal IR Remote Sensing	Wim Bastiaanssen
Microwave Remote Sensing	Susan Steele-Dunne

Lecture outline

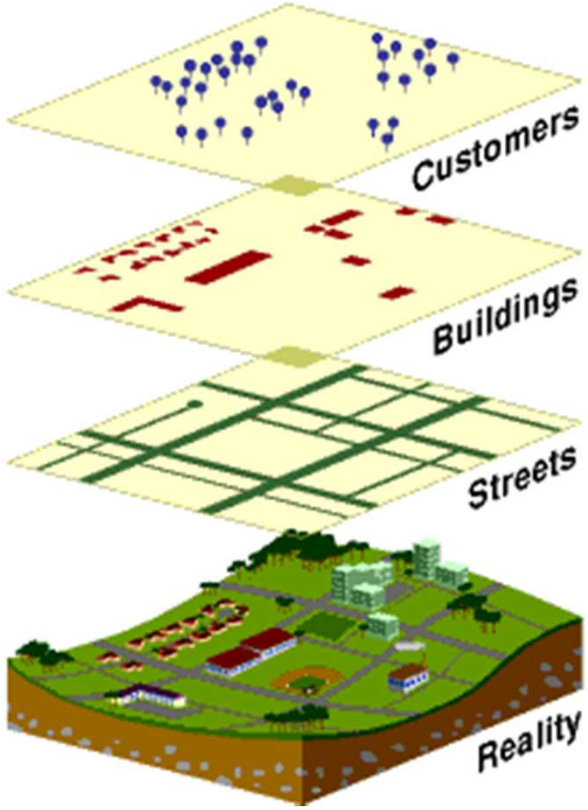
- Review Lecture 1 & Assignment 1
- Geoprocessing
- Feature data: Analysis Toolbox
- Raster data: Spatial Analyst Extension
- Geoprocessing framework
- Introduction to Assignment 2

Review Lecture 1
Introduction to GIS

- What is GIS?
- Data models to represent our world
- Functions of a GIS
- Real applications of GIS in Hydrology and Water Resources Management

What is a GIS?

- In a GIS, different types of information are represented as separate map layers
- Each layer is linked to descriptive information
- Layers are combined to make a map



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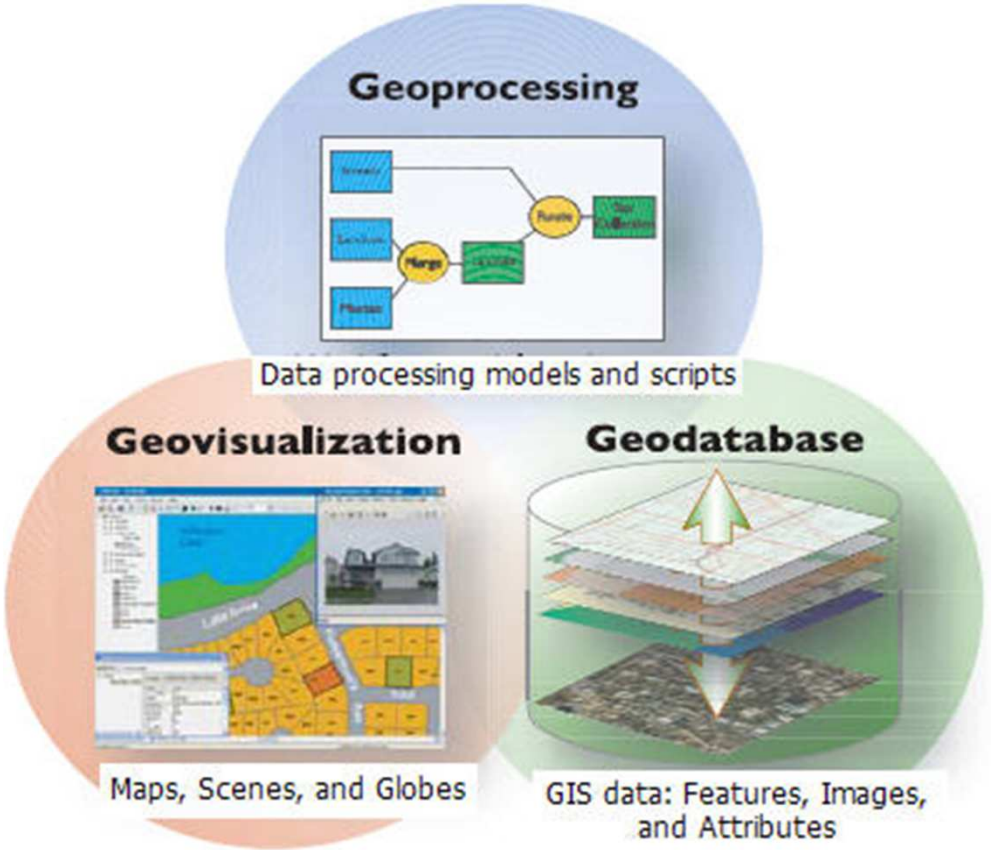
Geographical Information Systems

Key functions of a GIS:

- Data management
- Mapping and Visualization
- Geoprocessing



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Activity: GIS data models for Water Resources Management

Here are five tasks you might have as a water manager:

(a) Water supply demand and forecasting

(a) Wastewater and stormwater system design

(a) Flood damage assessment

(a) Drought monitoring & warning

(a) Designing a water quality monitoring network & database.

Activity: GIS data models for Water Resources Management

For your task:

1) **What data will you collect for your geodatabase?**

1) **Will that data be raster/feature/attribute data?**

1) **What will the attributes of the feature data be?**

1) **Can you think of 3 spatial questions you might ask?**
3 attribute questions?

Activity: GIS data models for Water Resources Management

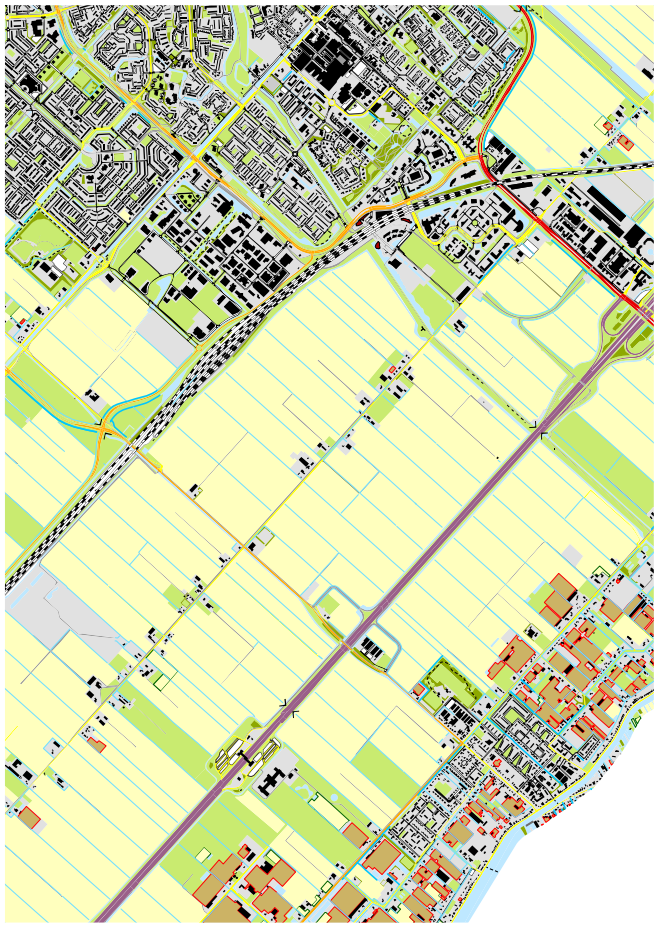
For your task:

1) **Think of a "big" problem that could be solved using GIS. (Finding a location for something, designing a new piece of infrastructure, minimizing damage due to some event)**

1) **What are the steps involved in solving your problem?**

1) **Are there any tools that you've seen today that might be helpful?**

Assignment 1: Exercise 3



TOP10

LGN6

TOP10_LGN6

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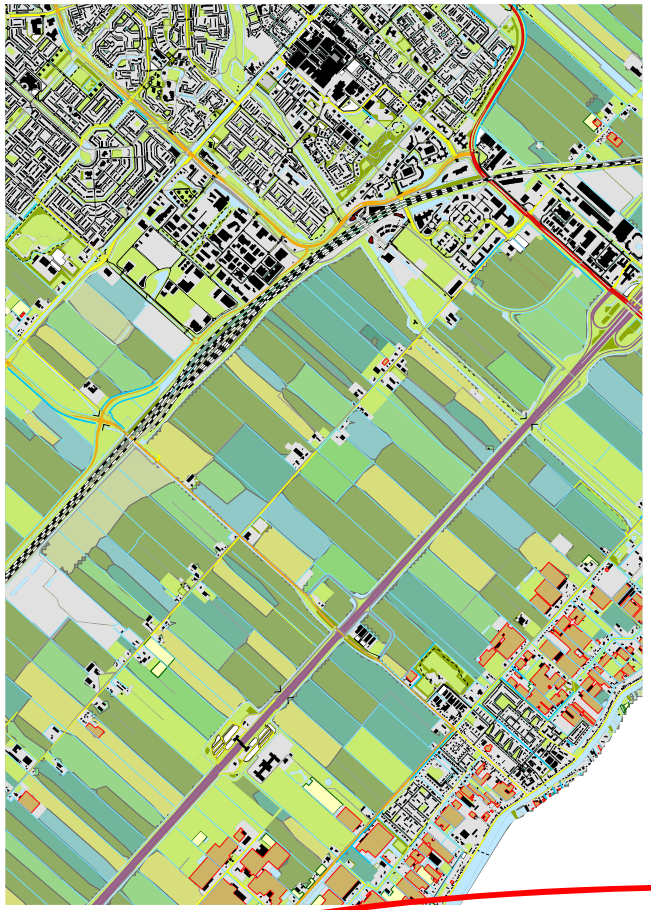
Assignment 1: Exercise 3

TOP10_LGN6



Generalize Lines

Eliminate small areas from LGN

Fine Tuning

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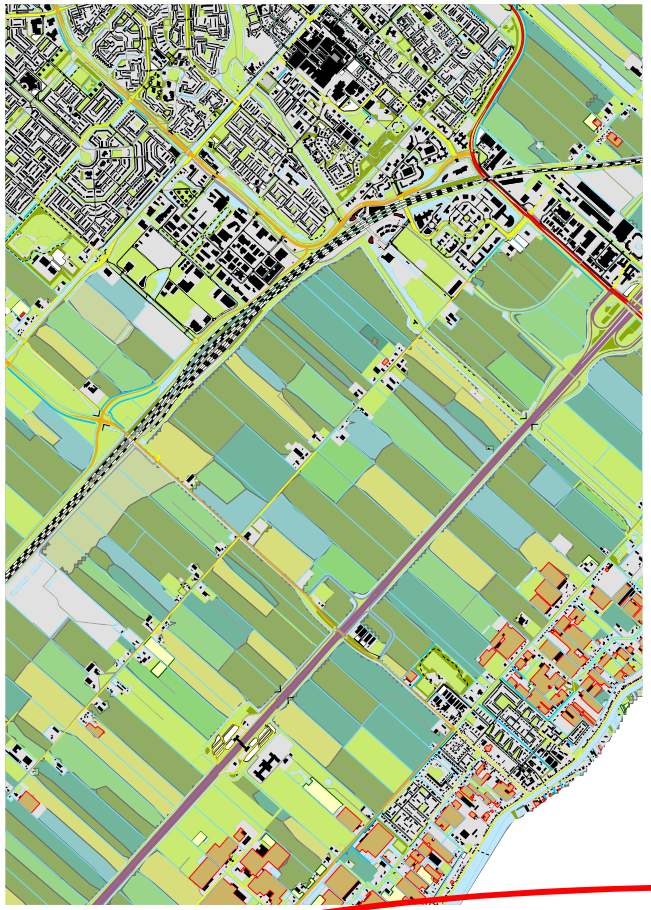
Assignment 1: Exercise 3

TOP10_LGN6



Generalize Lines

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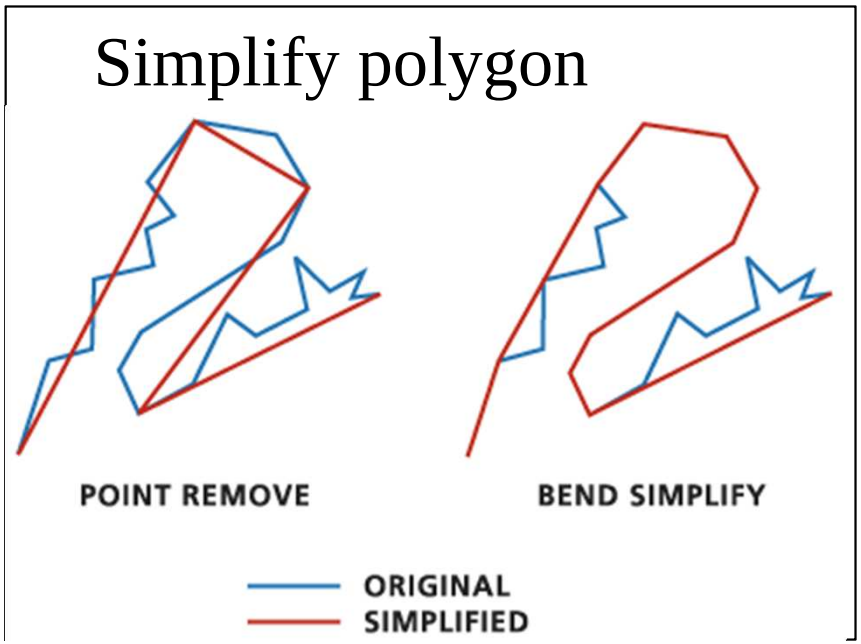
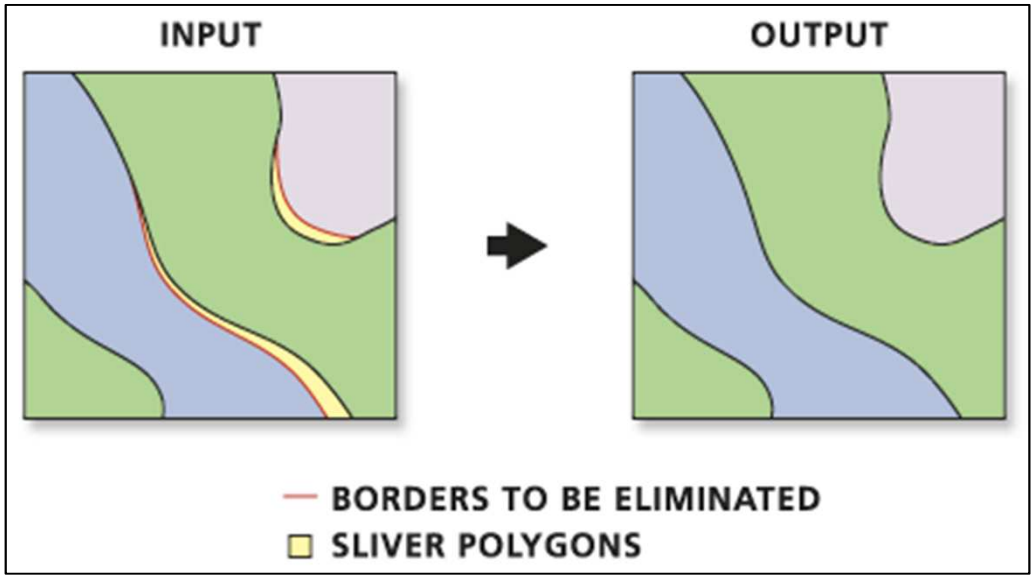
Assignment 1: Exercise 3

Simplify polygon



Generalization toolset: Eliminate



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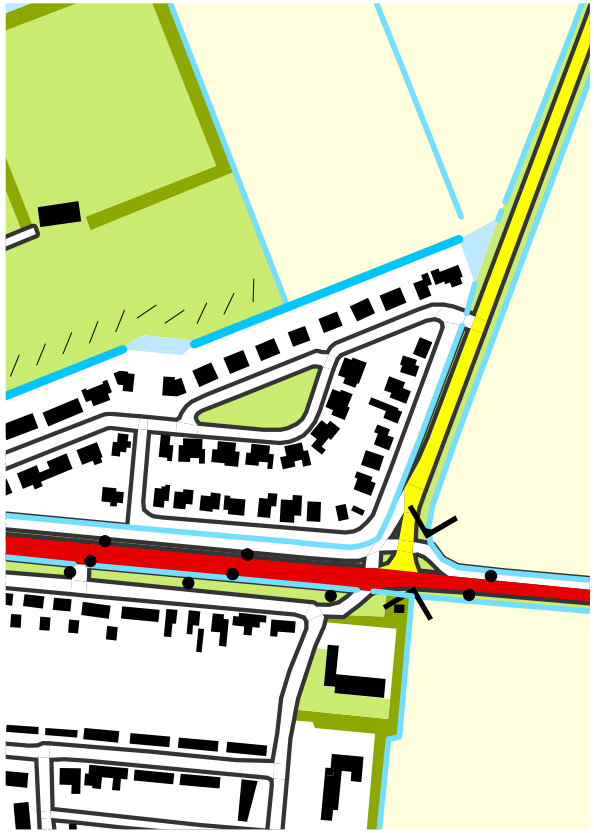
Assignment 1: Exercise 3

Good: Retained Buildings from TOP10NL



Not so good: Have lost good detail in urban areas!

Geoprocessing

Key functions of a GIS:

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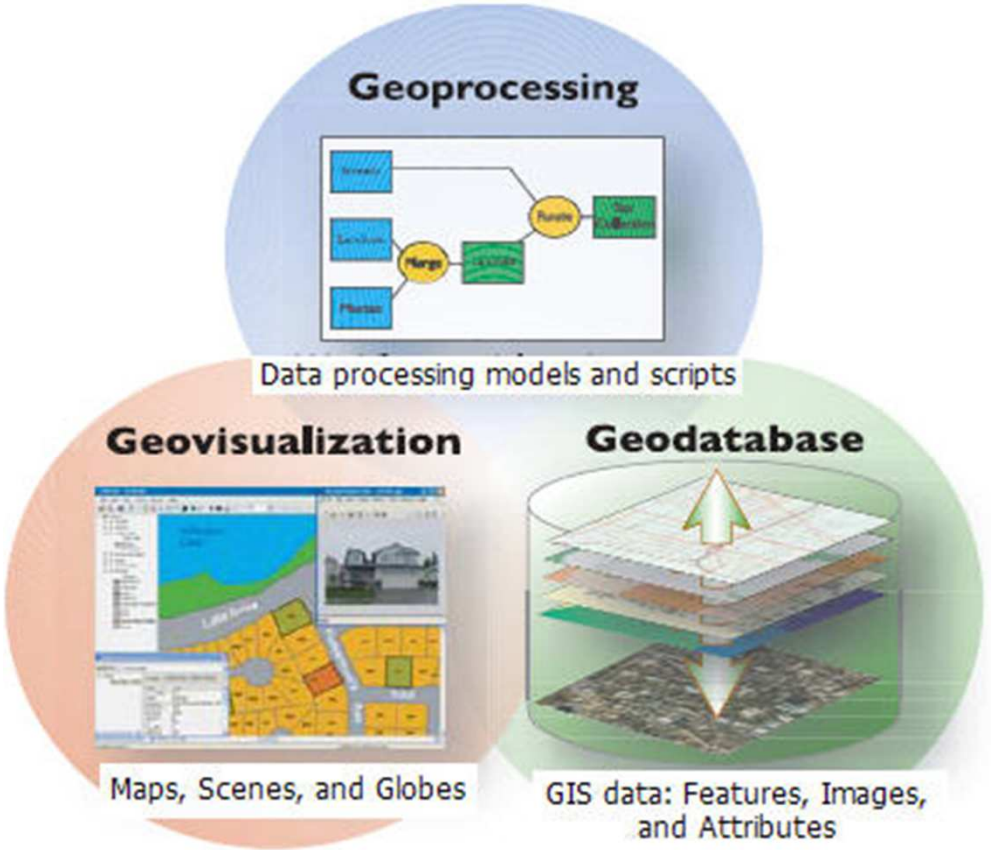
- Geoprocessing



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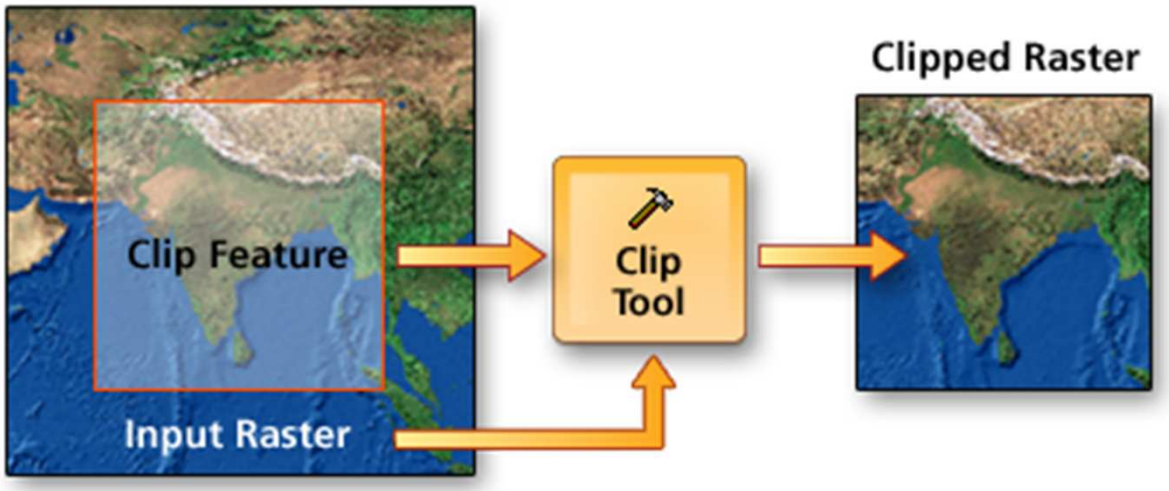
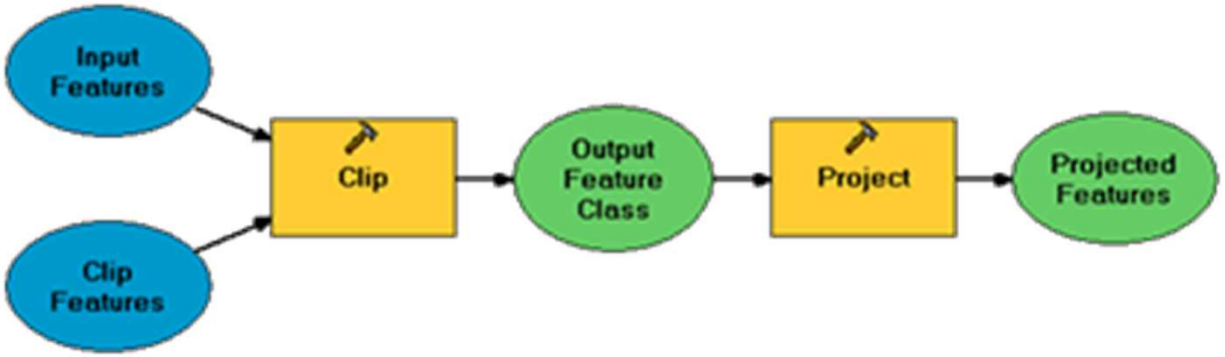
Geoprocessing?

Automating GIS tasks





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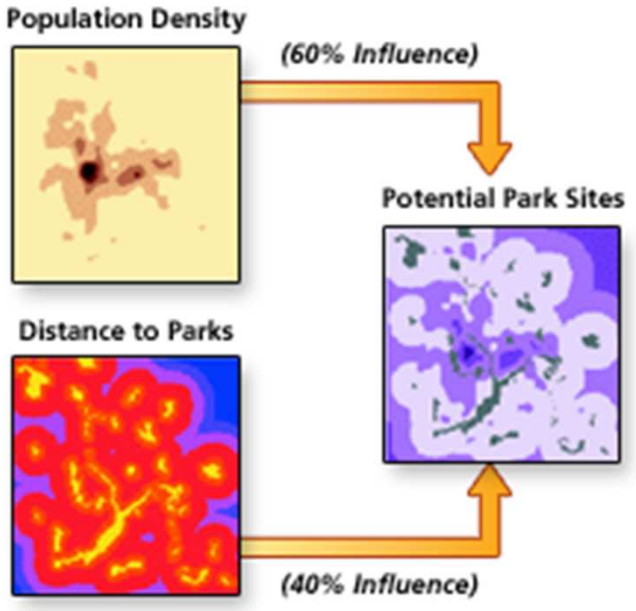
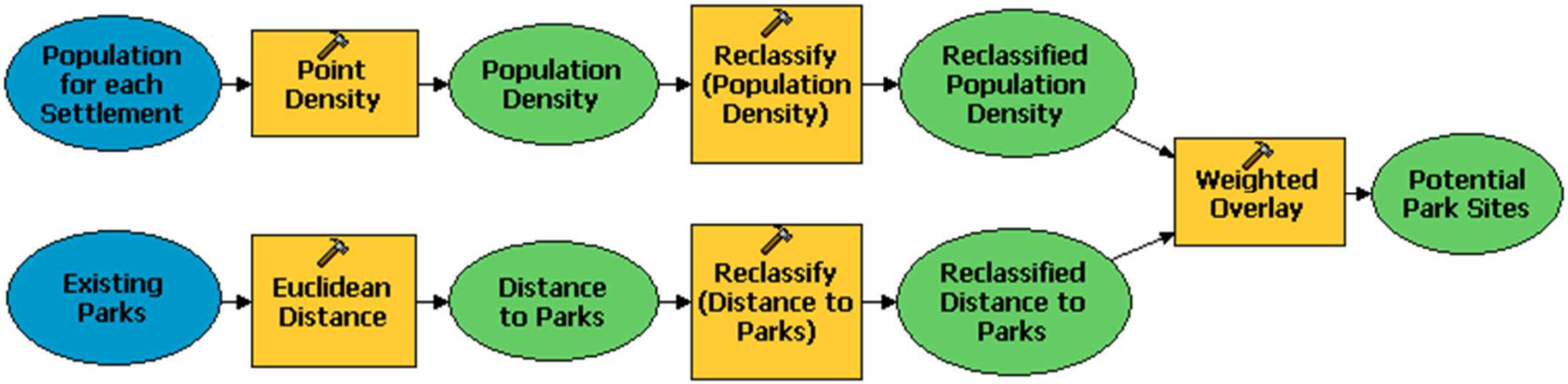
Geoprocessing

Modeling and analysis





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Geoprocessing

Feature data => Analyst toolbox

Raster data => Spatial Analyst Extension

Lecture outline

- Review Lecture 1 & Assignment 1
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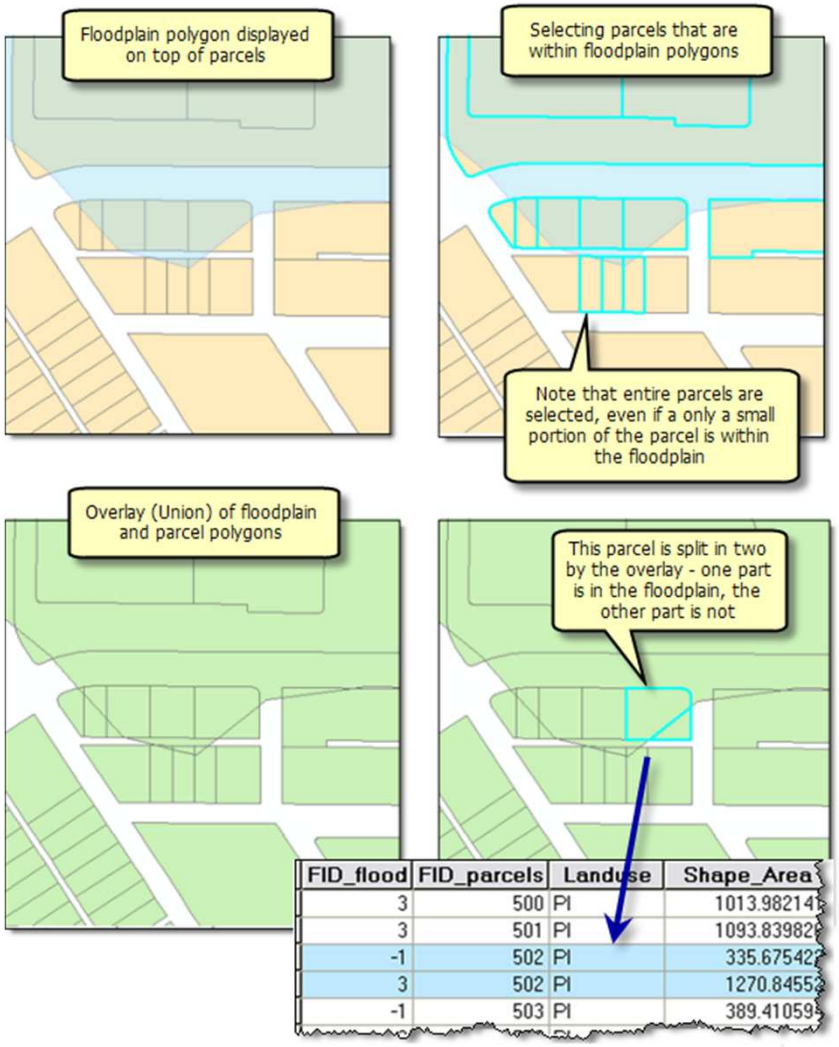
Feature Data: Analyst Toolbox

- Overlay
- Proximity
- Extract
- Statistics

Feature Data: Analyst Toolbox

Overlay

Whose land parcel got flooded?



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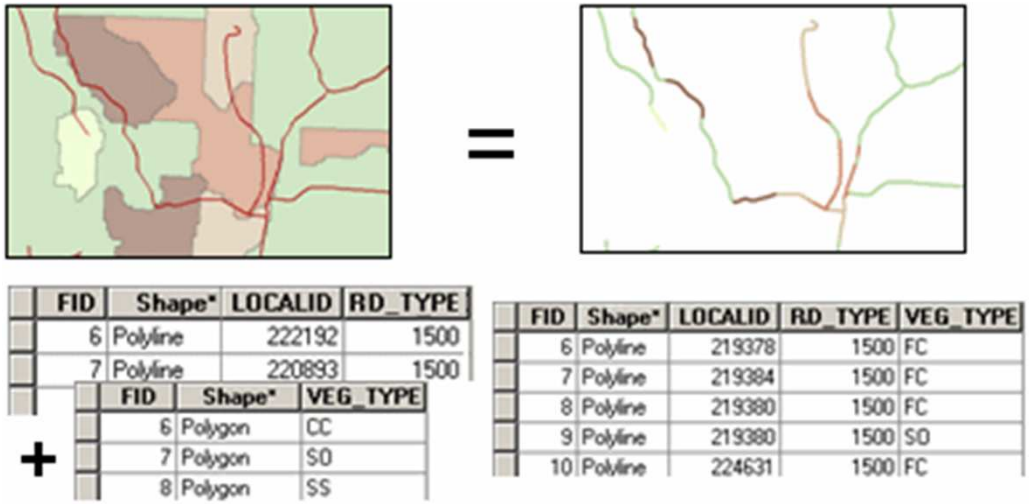
Feature Data: Analyst Toolbox

Overlay

What vegetation types are along logging roads?



FID	Shape*	LOCALID	RD_TYPE
6	Polyline	222192	1500
7	Polyline	220893	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	219380	1500	SO
10	Polyline	224631	1500	FC

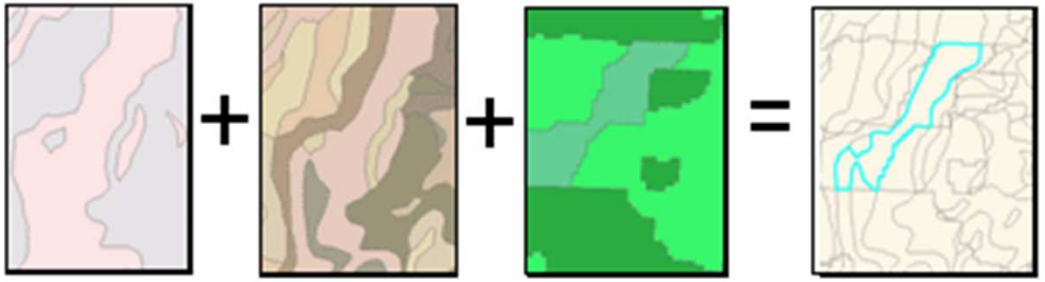
Feature Data: Analyst Toolbox

Overlay

Hydrotopes:

Units that are hydrologically similar.

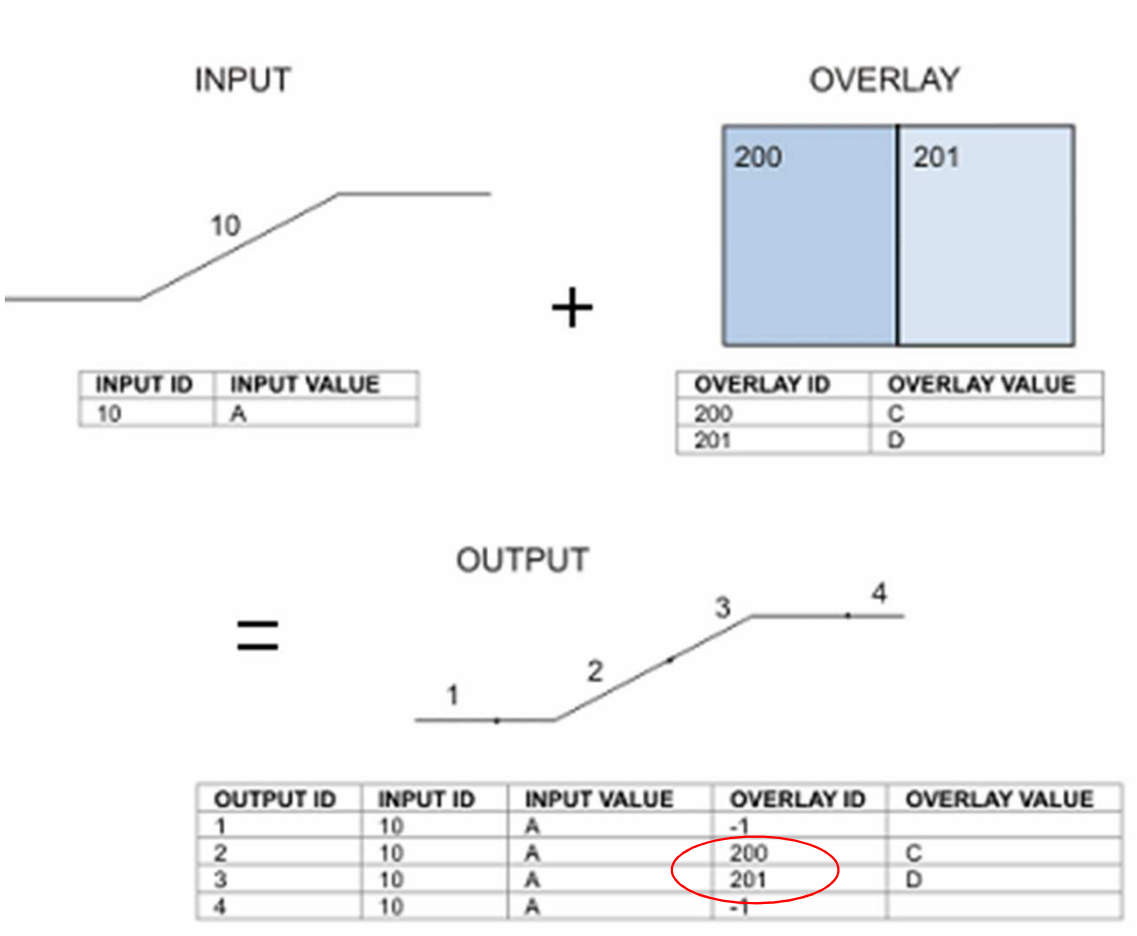
Similar soil, slope and vegetation?



	FID	Shape*	FID_soils	CODE	CLASS	FID_sl	SLOPE	FID_veg	DET_TYPE
	3039	Polygon	508	38F	6	0	60	117	A
	3040	Polygon	508	38F	6	0	60	119	SS
	3041	Polygon	508	38F	6	0	60	157	U
	3042	Polygon	508	38F	6	0	60	158	A
	3043	Polygon	508	38F	6	0	60	160	FC

Feature Data: Analyst Toolbox

Overlay (e.g. cost of replacing watermain)



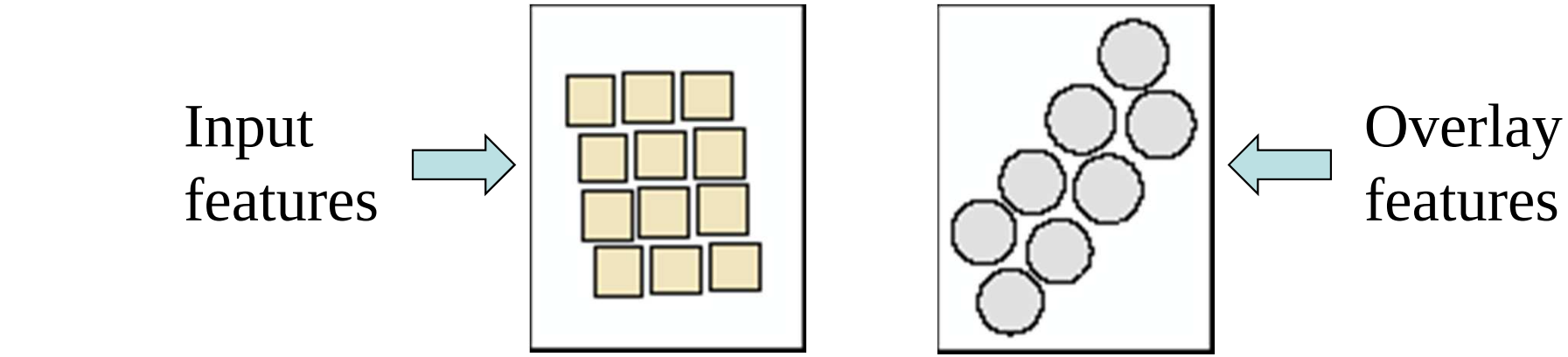
INPUT ID	INPUT VALUE
10	A

OVERLAY ID	OVERLAY VALUE
200	C
201	D

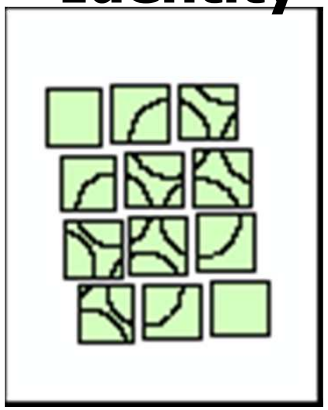
OUTPUT ID	INPUT ID	INPUT VALUE	OVERLAY ID	OVERLAY VALUE
1	10	A	-1	
2	10	A	200	C
3	10	A	201	D
4	10	A	-1	

Feature Data: Analyst Toolbox

Overlay

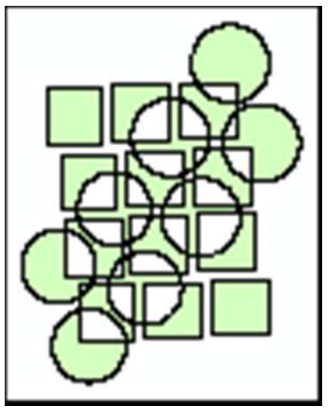


Identity

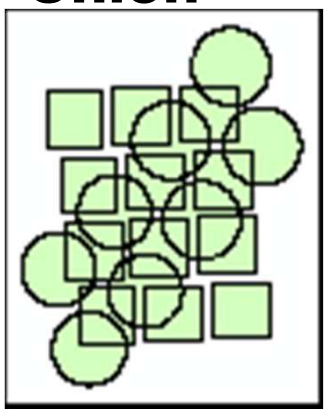


Intersect

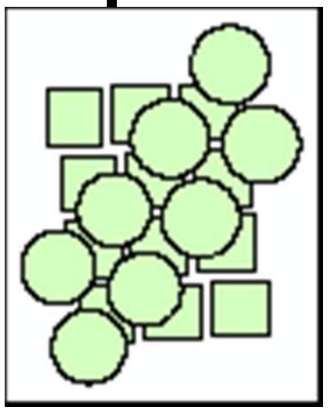
Symmetric Difference



Union



Update



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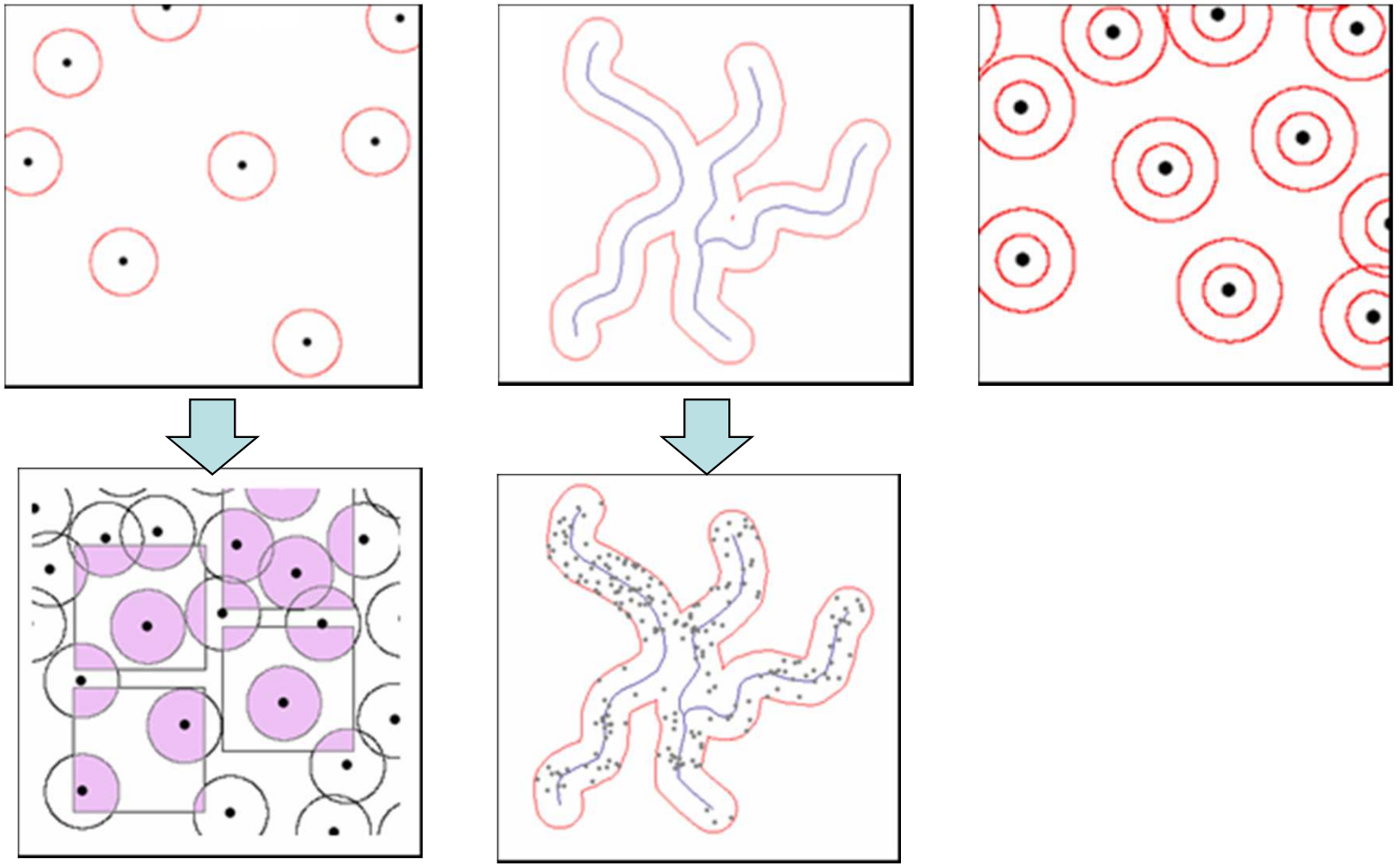
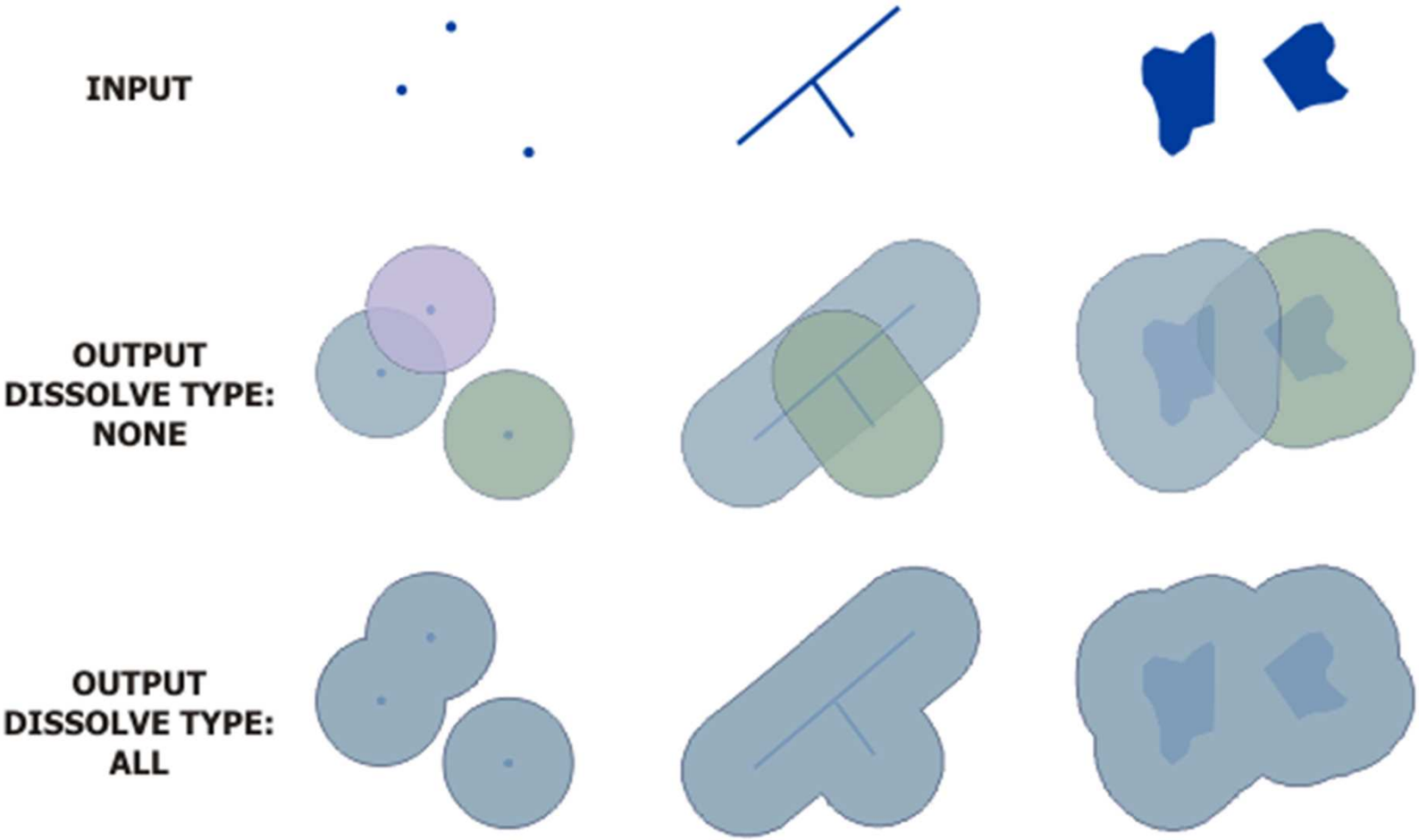
Feature Data: Analyst Toolbox

Proximity: Buffer



Feature Data: Analyst Toolbox

Proximity: Buffer



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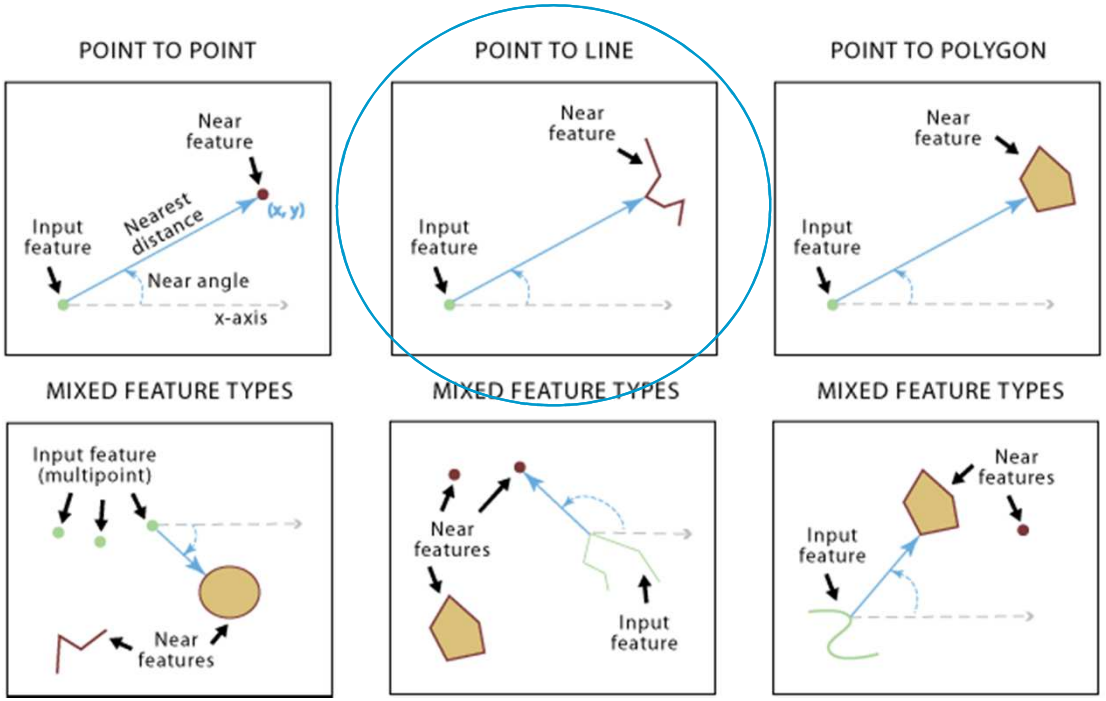
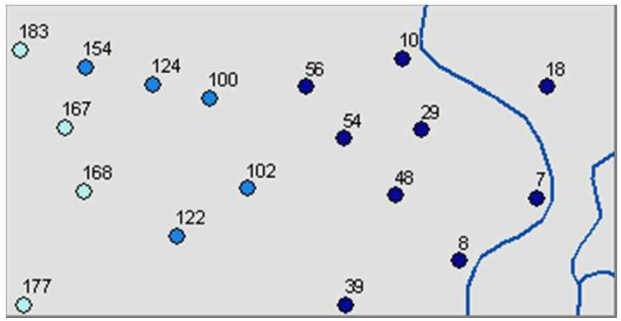
Feature Data: Analyst Toolbox

Proximity: Near





	FeatureID	NearDist	NearAngle
	0	56	18.394009
	1	122	-31.848772
	2	195	-2.41069
	3	48	-35.72168
	4	105	-13.856518
	5	177	-10.703785
	6	75	-23.185714

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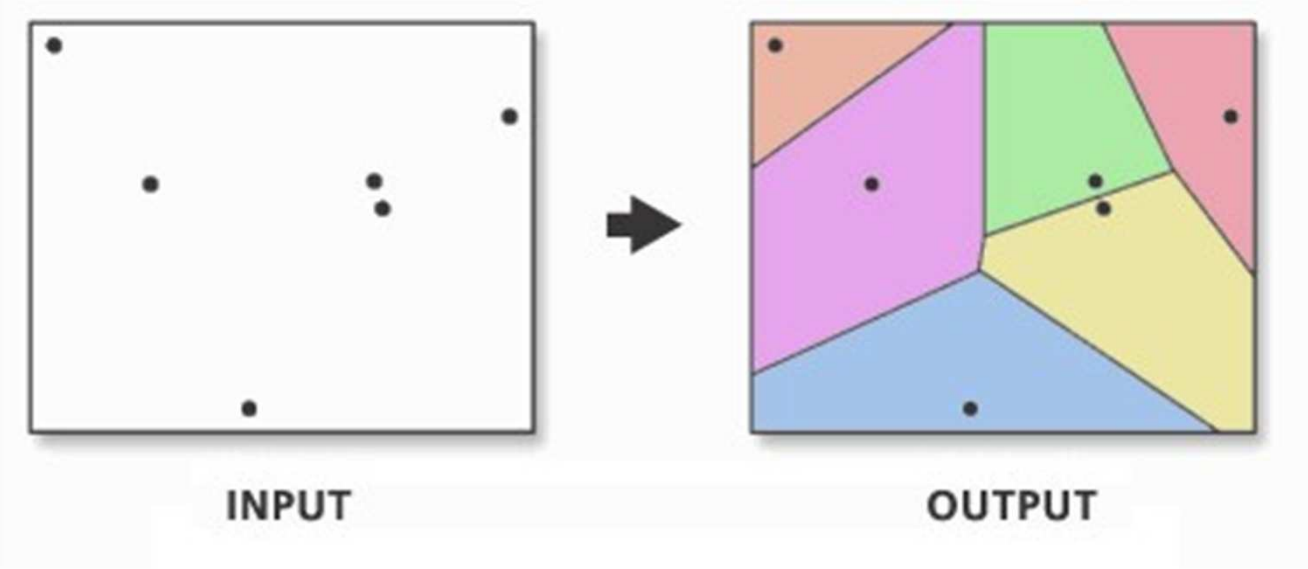
Feature Data: Analyst Toolbox

Proximity: Create Thiessen Polygons



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Feature Data: Analyst Toolbox

Proximity: Create Thiessen Polygons

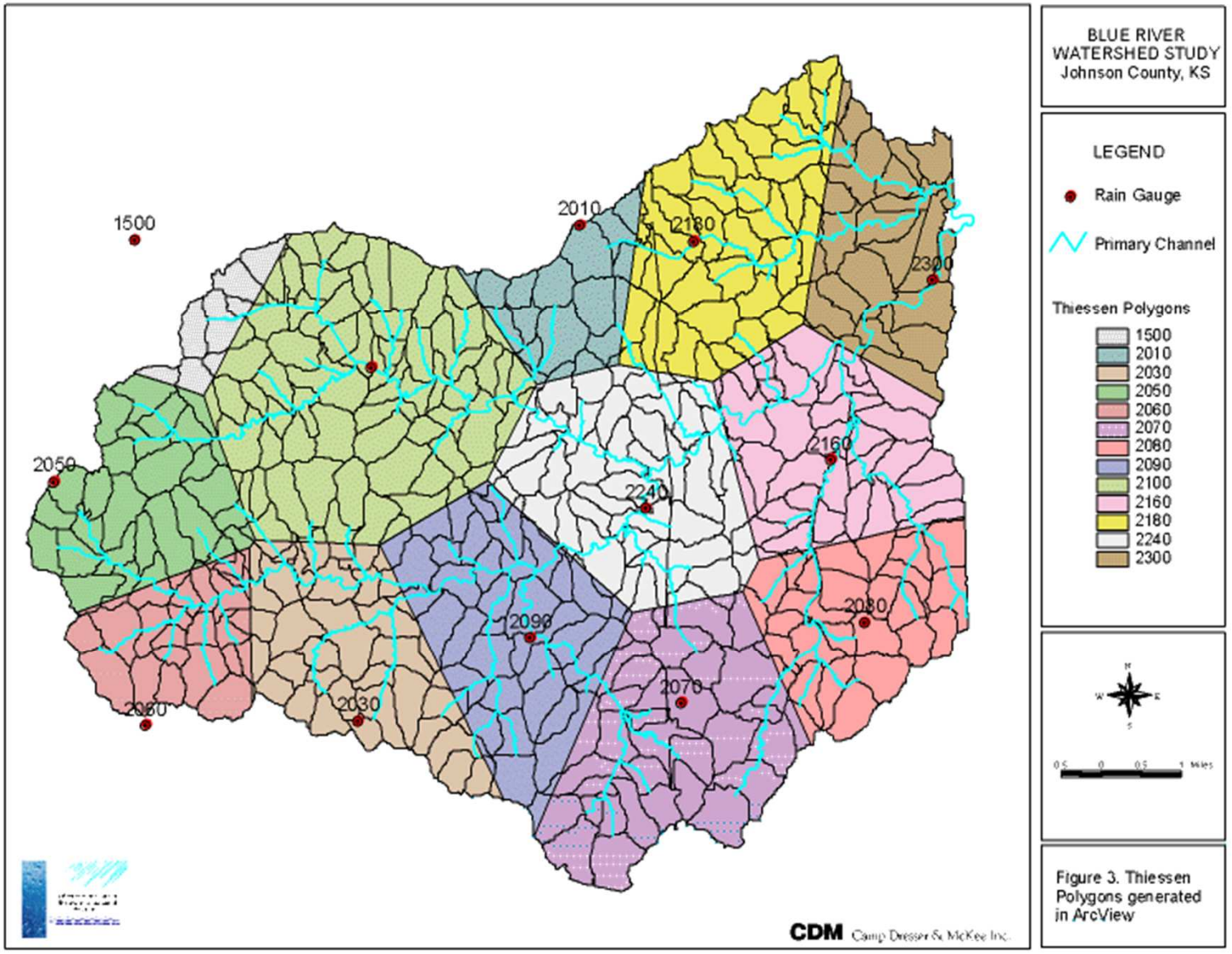
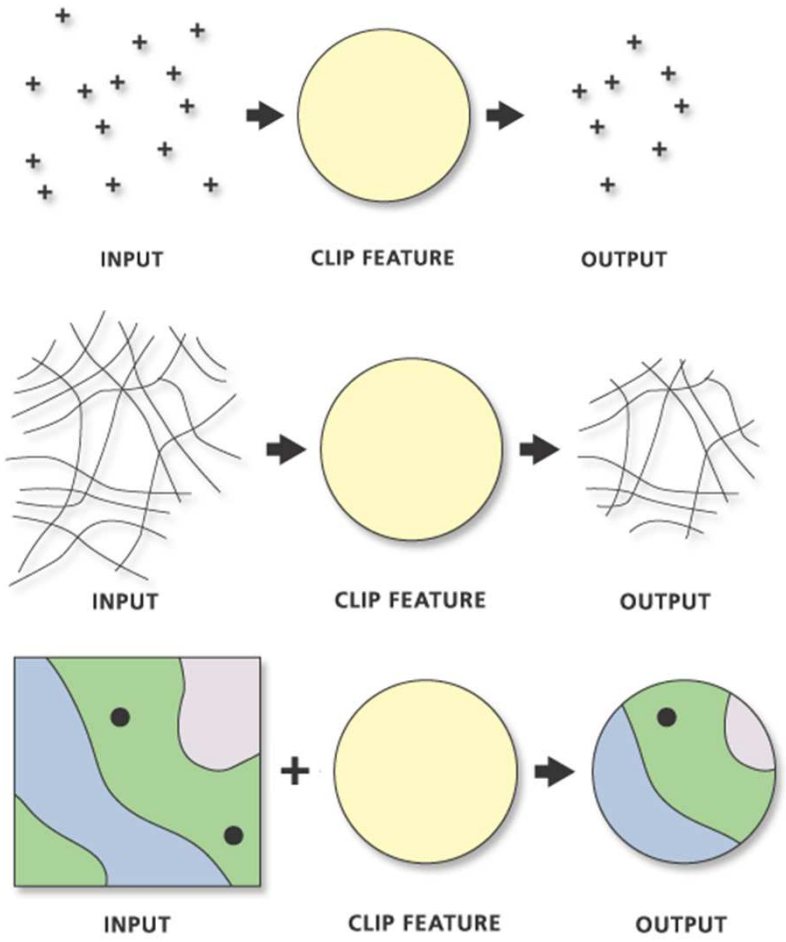


Figure 3. Thiessen Polygons generated in ArcView

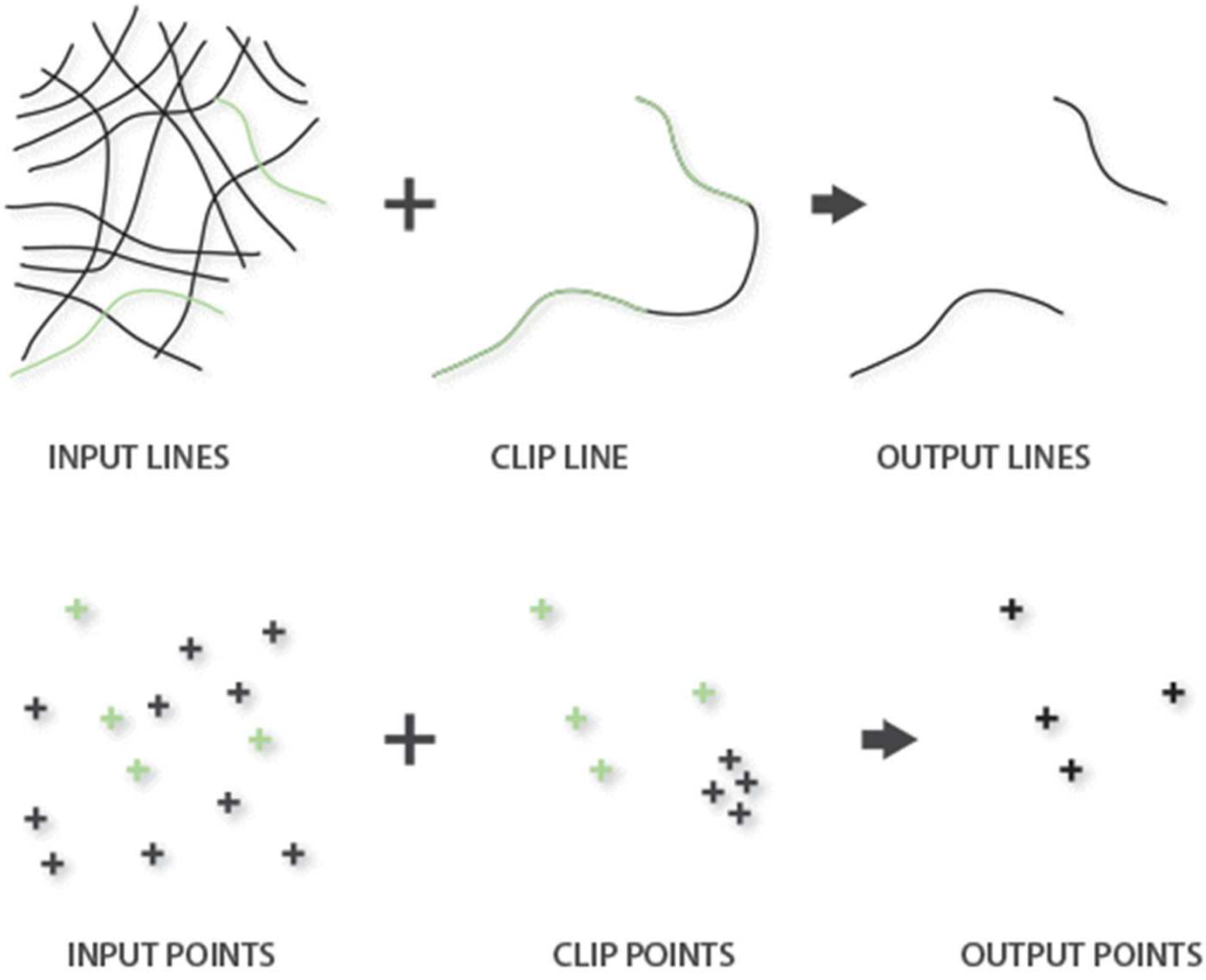
Feature Data: Analyst Toolbox

Extract: Clip



Feature Data: Analyst Toolbox

Extract: Clip



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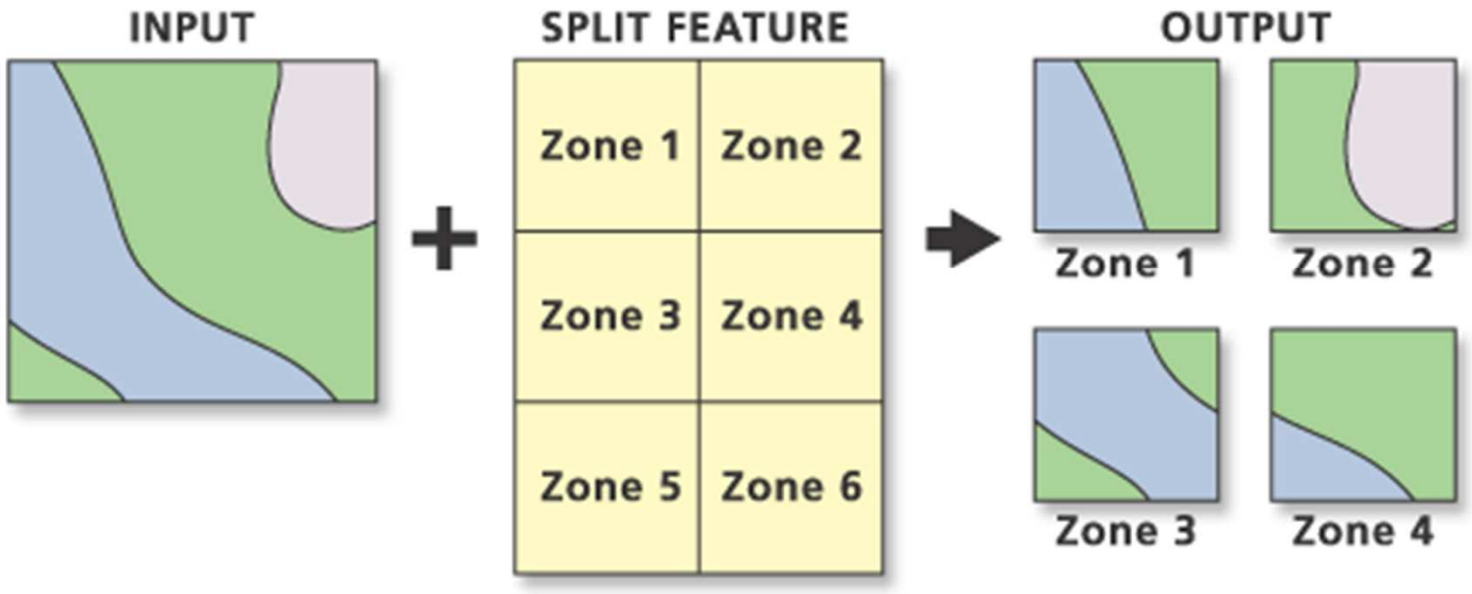
Feature Data: Analyst Toolbox

Extract: Split



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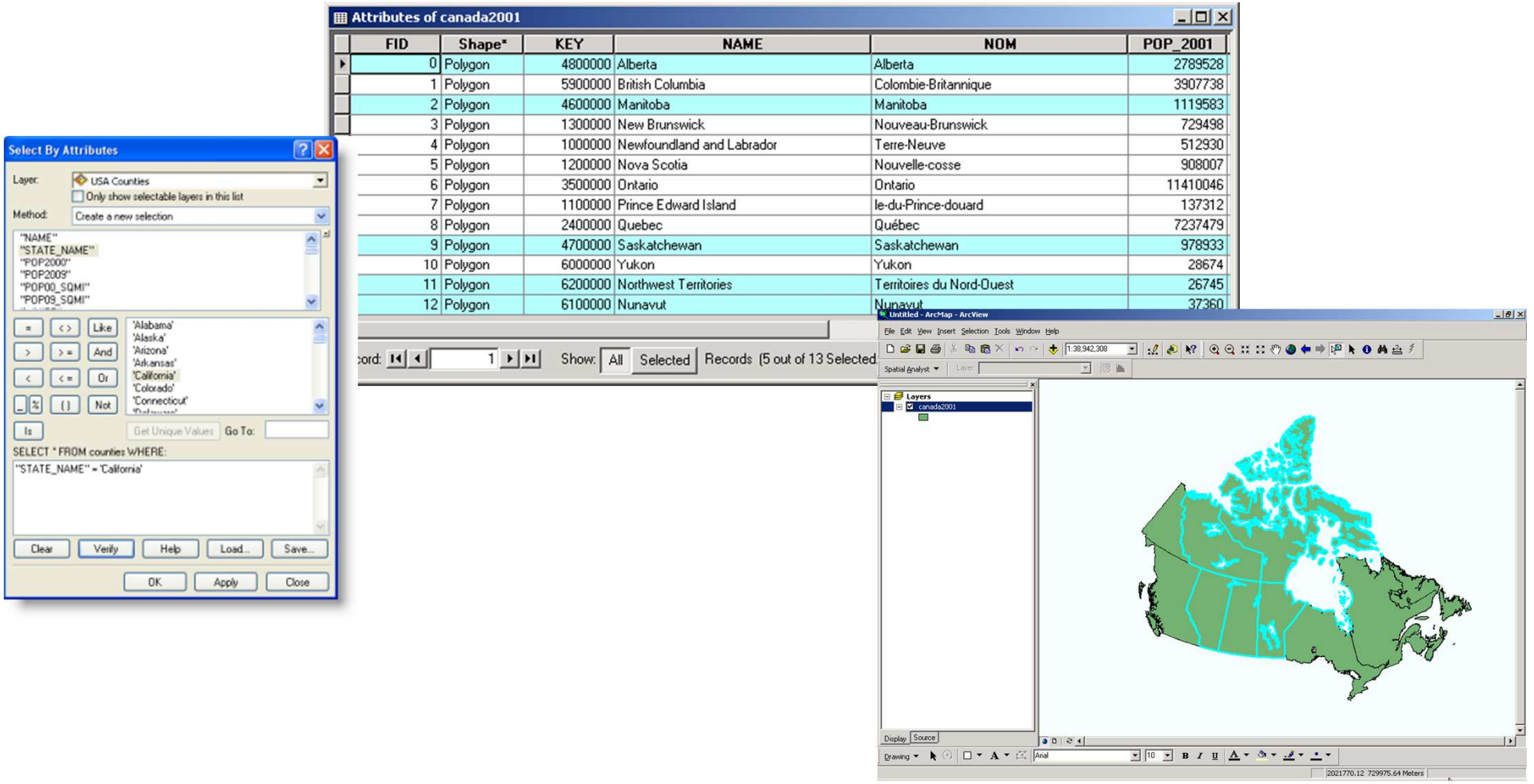
Feature Data: Analyst Toolbox

Extract: Select



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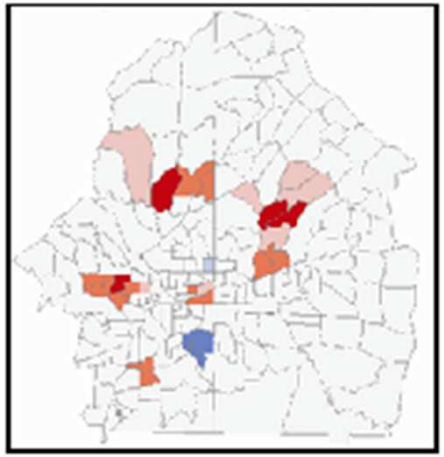
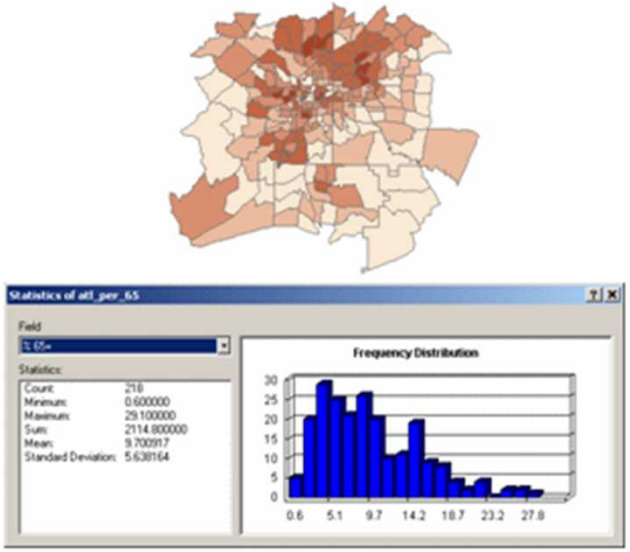
Feature data: Statistical Analysis

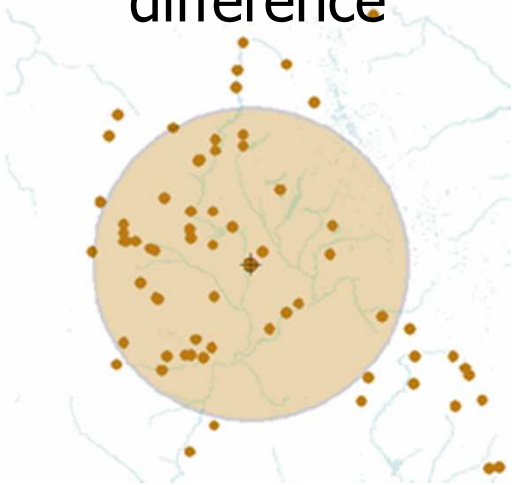
Statistical significance



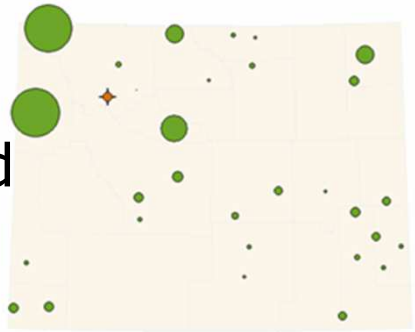
Summary statistics and histogram



Standard difference



Weighted spatial statistics



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Activity: Feature Data – Analyst Toolbox

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(a) Wastewater and stormwater system design

(a) Flood damage assessment

(a) Drought monitoring & warning

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Activity: Feature Data – Analyst Toolbox

For your task:

What feature data did you have (from last week!)?

Think of an example of when and how you might apply each of the following tools to your data:

Overlay
Proximity
Extract

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Raster Data: Spatial Analyst Extension

Map Algebra

Spatial Analyst Toolbox

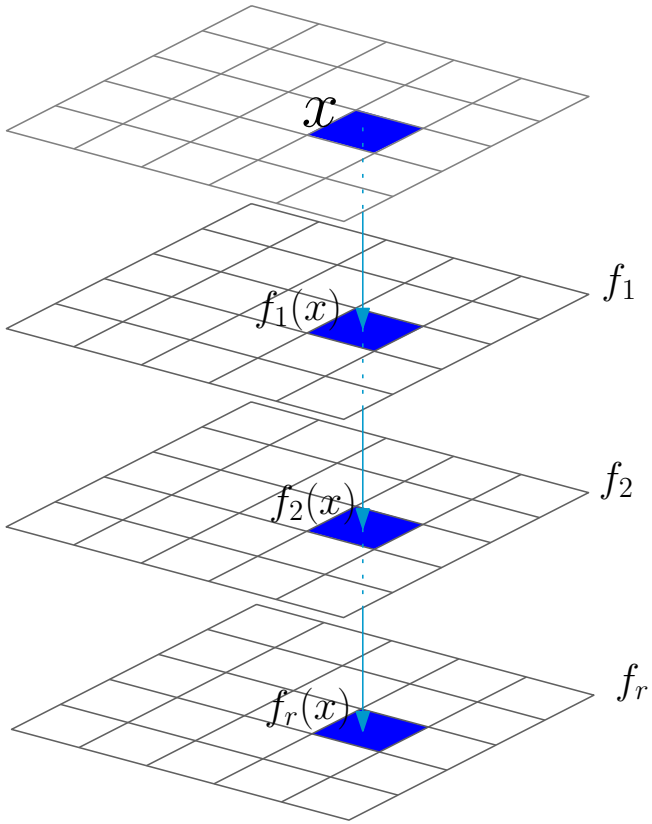
- Map Algebra Toolset (incl. Raster Calculator)
- Extraction Toolset
- Overlay Toolset
- Distance Toolset
- Surface Toolset

Image Classification

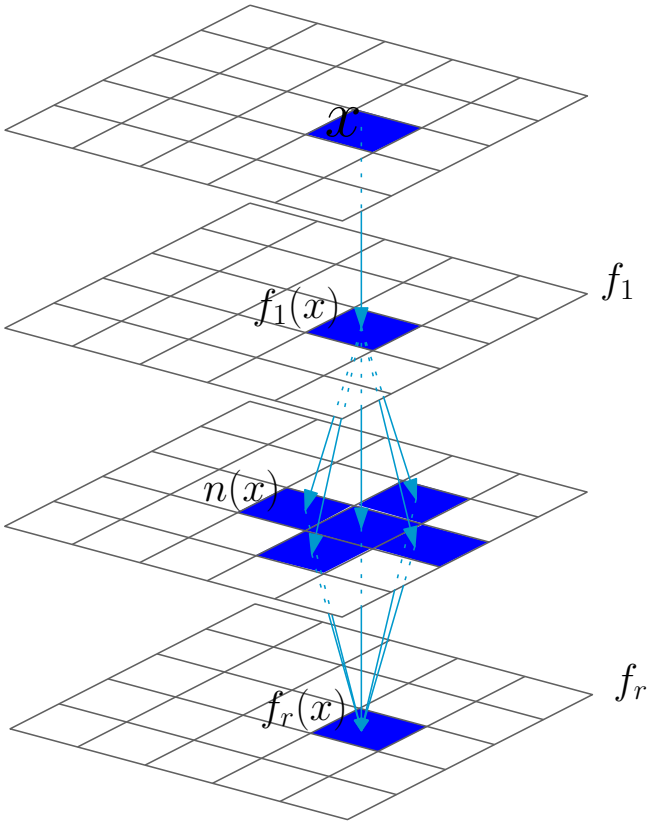
Map Algebra

- Dana Tomlin (1983)
- "Algebra" because maps are treated as variables and manipulated or combined using algebraic expressions
- Organizes all GIS operations on a ***raster*** into three types
  - Local operations are determined by the attributes of each cell alone
  - Focal operations are determined by a cell's neighbors
  - Zonal operations apply to all contiguous cells with the same value

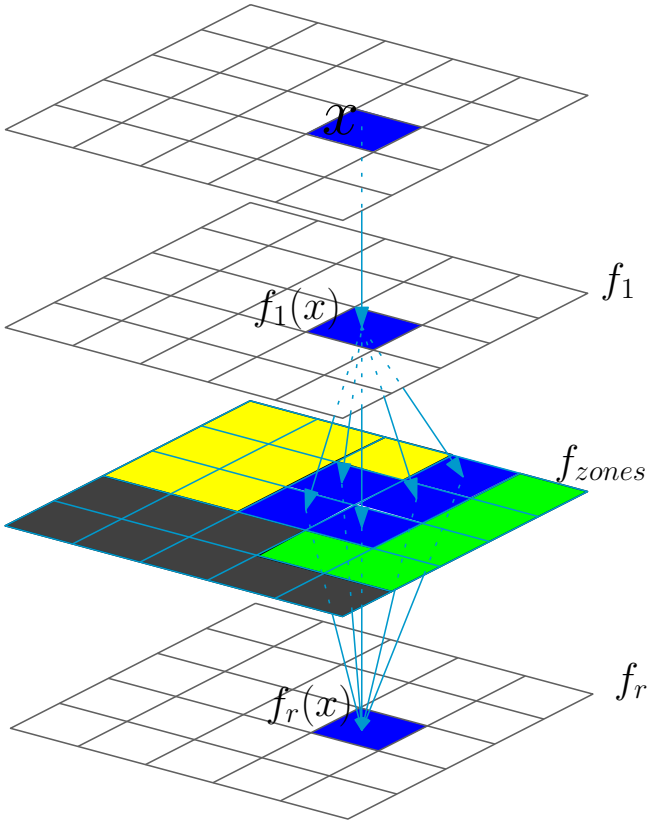
Map Algebra



Local operation



Focal operation



Zonal operation

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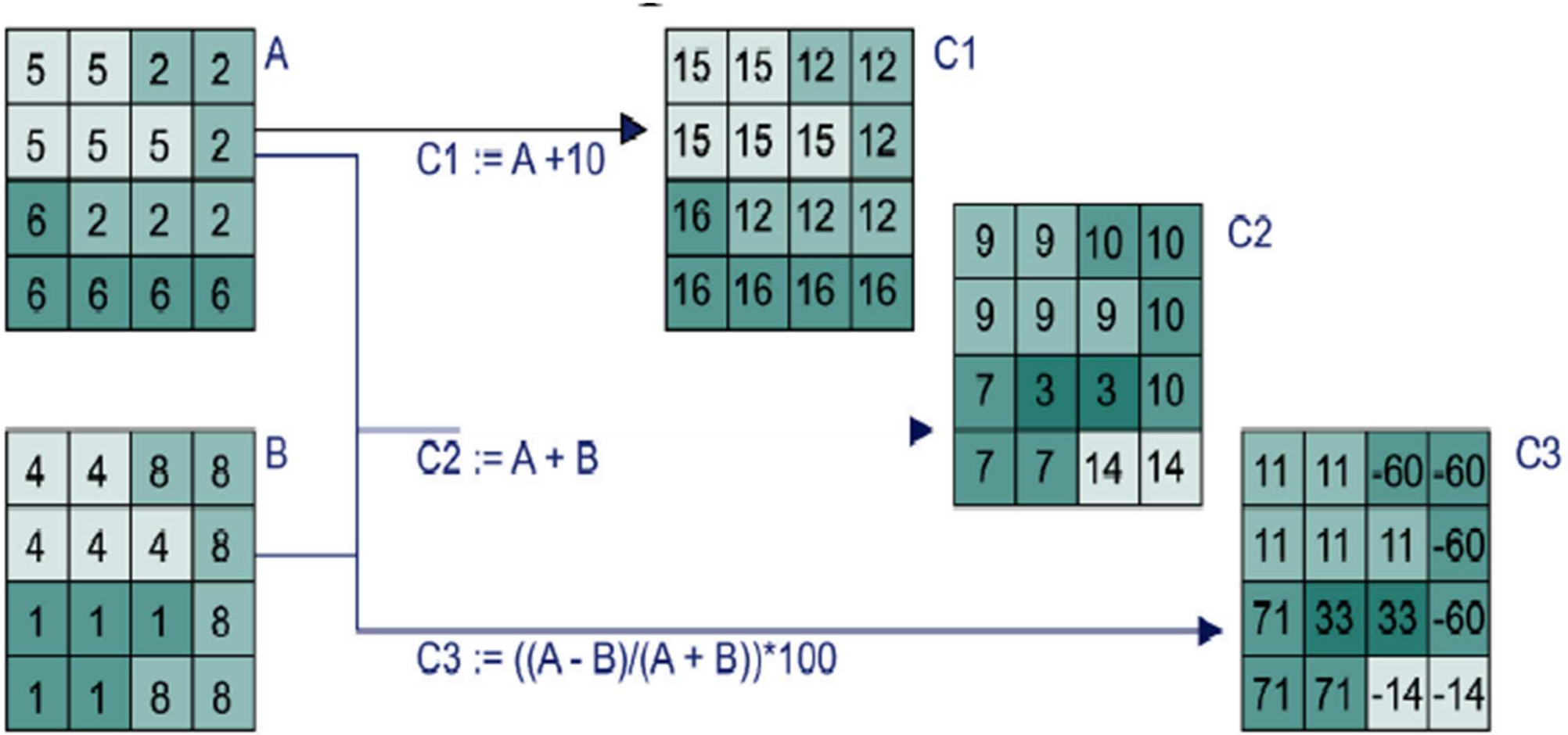
Map Algebra: Local Operations



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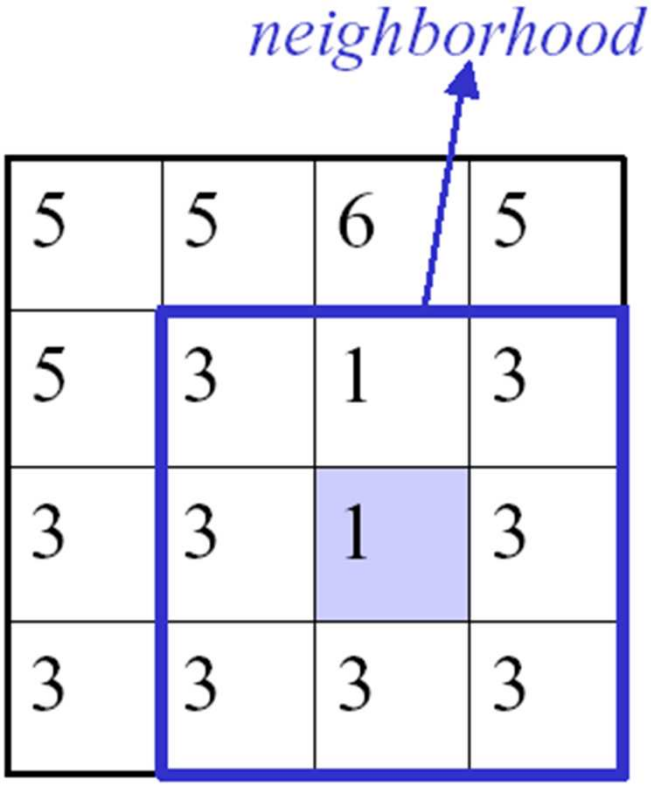
Map Algebra: Focal Operations

- Operators:
  - mathematical
  - statistical
- Example 3 x 3 neighborhood:
- O(i,j) = Function{

  I(i-1,j-1), I(i-1,j), I(i-1,j+1),
  I(i,j-1), I(i,j) I(i,j+1),
  I(i+1,j-1), I(i+1,), I(i+1,j+1)

  }



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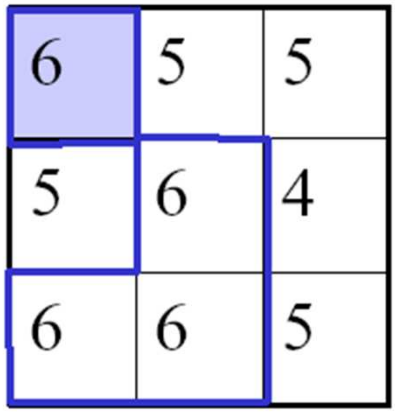
Map Algebra: Zonal Operations

- Zone:
  - Any two or more connected cells with the same value (e.g. covering the class urban area)
- Neighborhood is the zone to which the target cells belong
- Usually, one layer defines the zones, another layers contains the values on which the operation is carried out

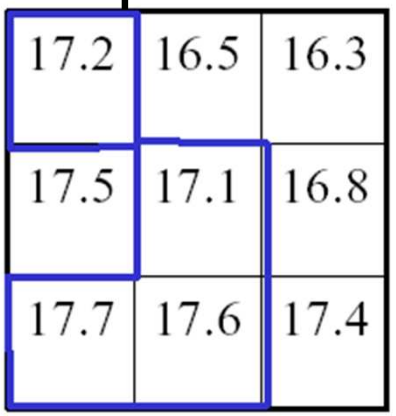
Map Algebra: Zonal Operations

Example

- Calculate for the zone with land use 6 the average height: O(i,j) = 17.4

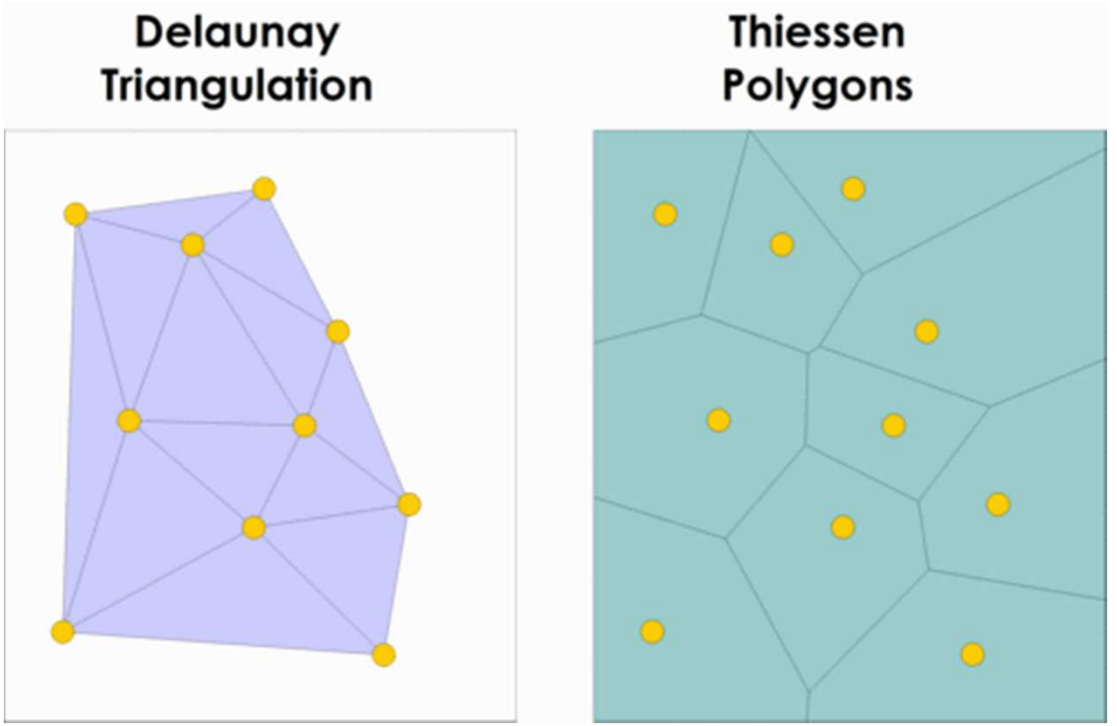


Land use map



Digital Elevation Model

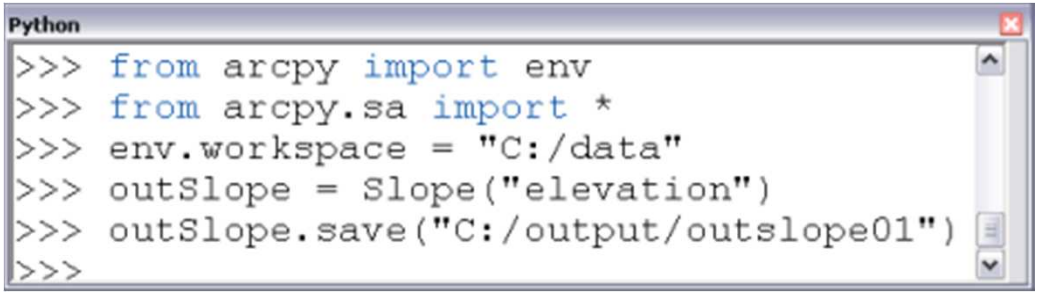
Map Algebra: Global Operations



- Euclidean distance
- Cost distance
- Voronoi polygons, Theissen polygons

Use Map Algebra in ArcGIS 10:

- Raster Calculator
- Python Window



- Python Integrated Development Environment (IDE)

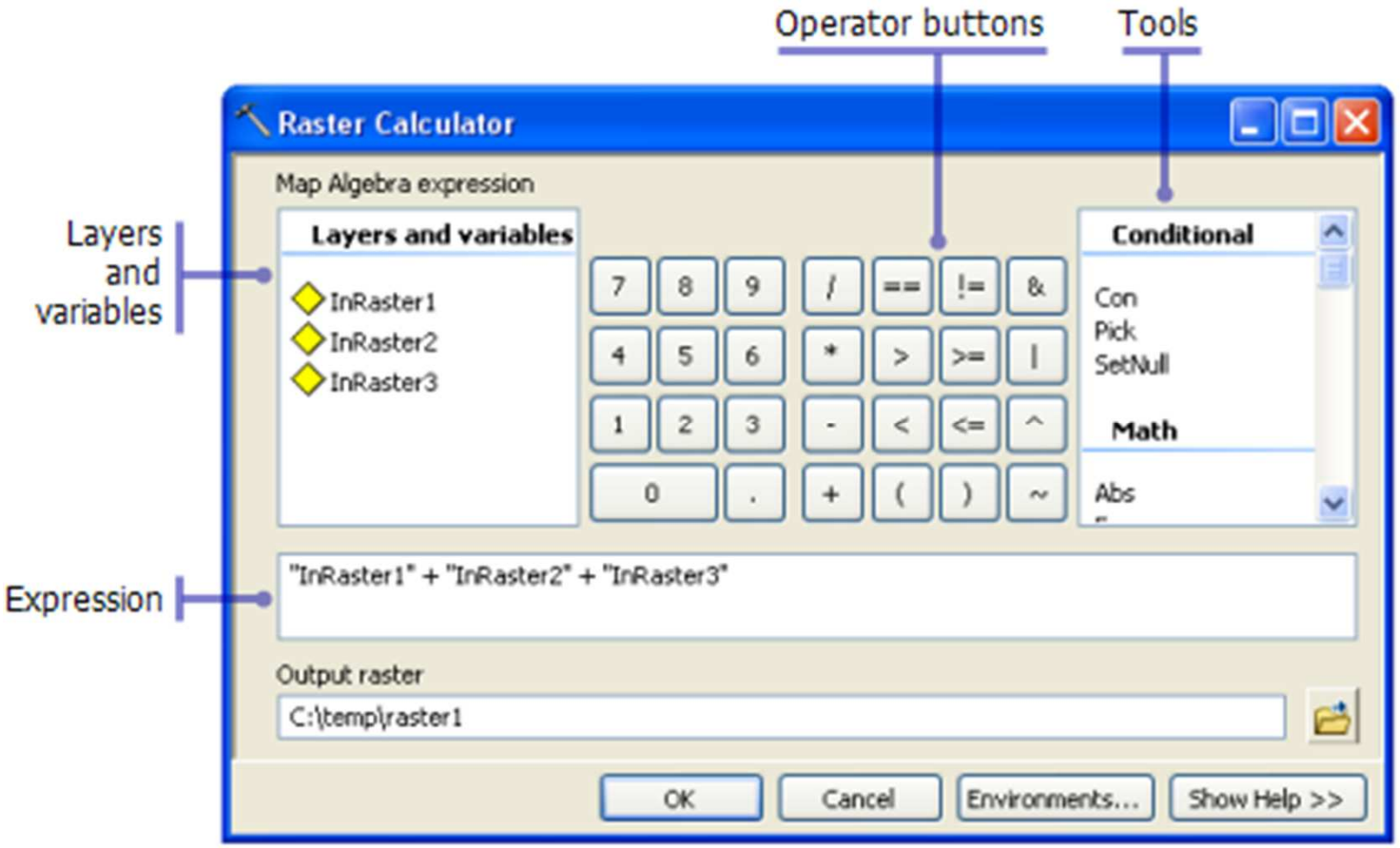
```
# Name: Slope
# Description: Identifies the rate of maximum change
#     in z-value from each cell.
# Requirements: Spatial Analyst Extension
# Author: ESRI

# Import system modules
import arcpy
from arcpy import env
from arcpy.sa import *

# Set environment settings
env.workspace = "C:/data"

# Set local variables
inRaster = "elevation"
outMeasurement = "DEGREE"
zFactor = 0.3043
```

Map Algebra: Raster Calculator



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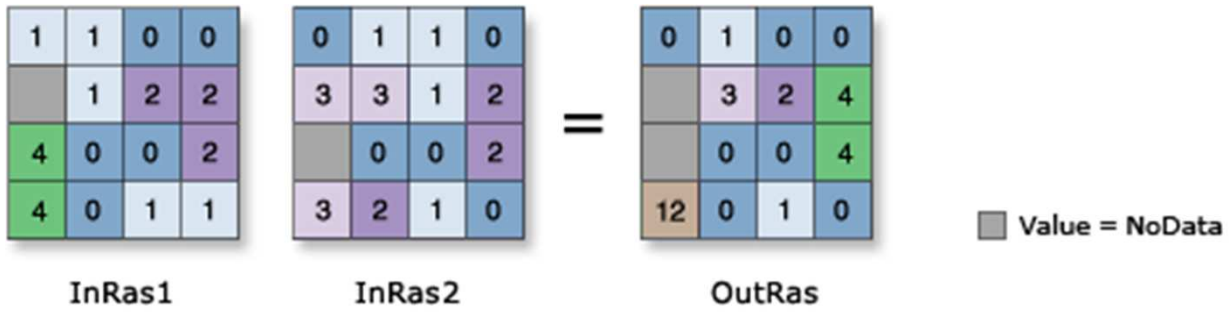
Map Algebra: Raster Calculator

Raster Calculator Operations

OutRas = Raster("InRas1") * Raster("InRas2")

Arithmetic
(e.g. +,-,*, /,%)



Math
(e.g. Sin, Cos, Abs, Neg, Log etc..)

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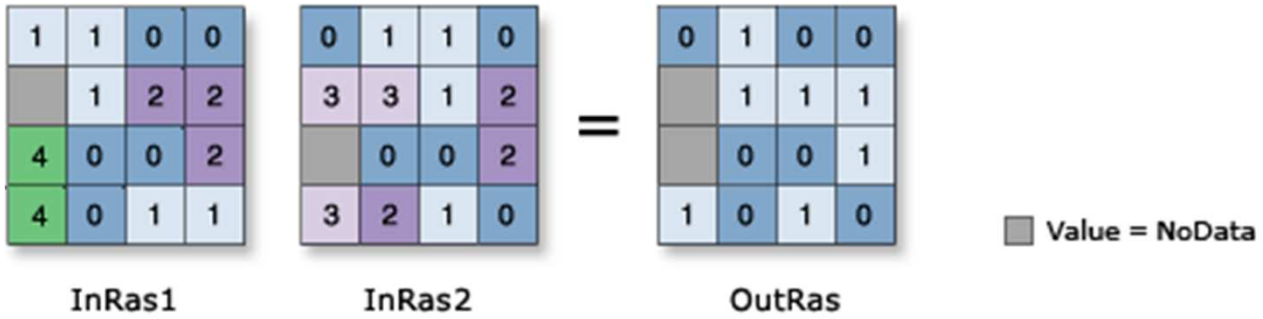
Map Algebra: Raster Calculator

Raster Calculator Operations

Boolean
(e.g. &, ~,|, ^)

OutRas = Raster("InRas1") & Raster("InRas2")



Relational
(e.g. >, >=, ==, …)

OutRas = Raster("InRas1") >= 2

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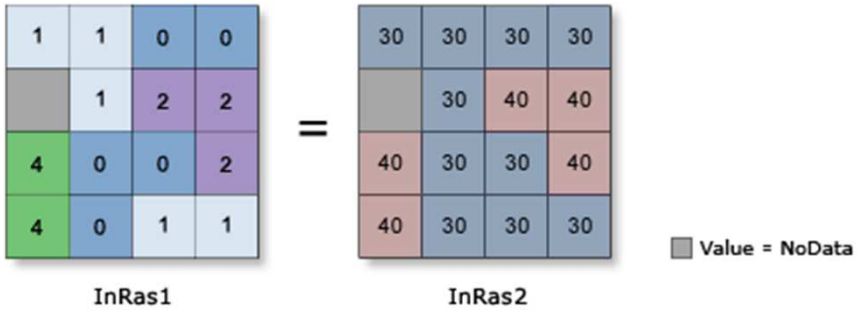
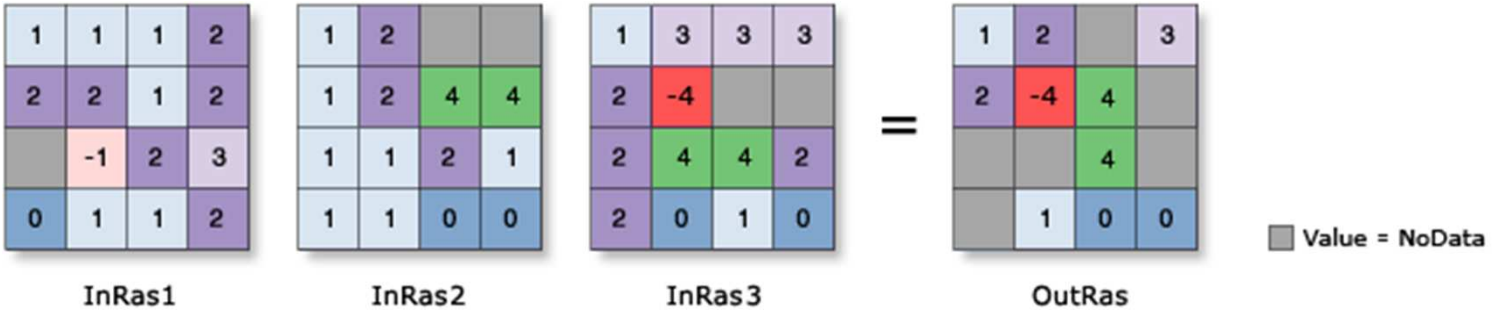
Map Algebra: Raster Calculator

Conditional Operations

OutRas = **Con**(InRas1, 40, 30, "Value >= 2")



OutRas = **Pick**(InRas1, [InRas2, InRas3])



OutRas =
SetNull(InRas1, InRas2, "Value = 4")

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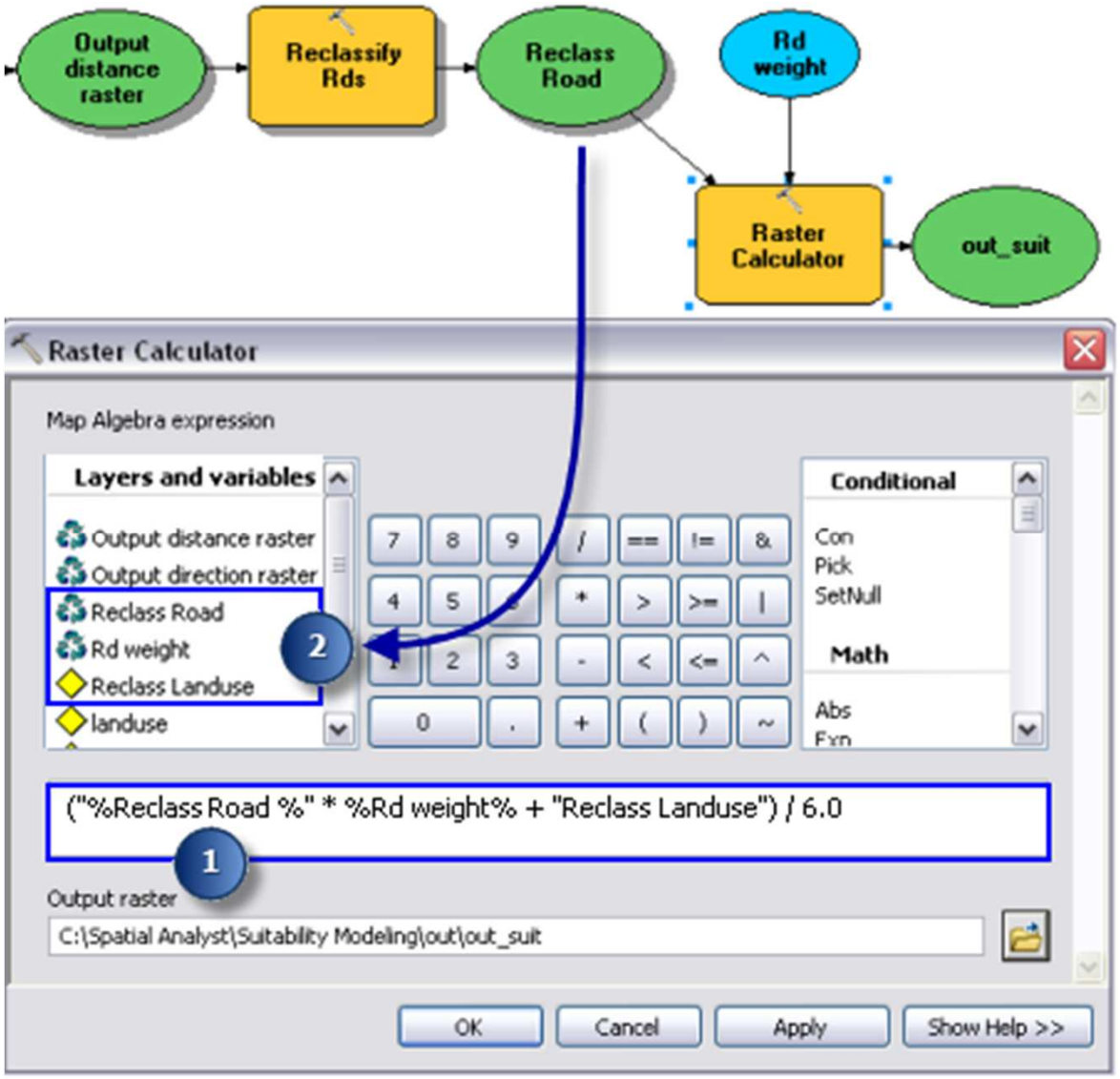
Map Algebra: Raster Calculator

Raster calculator in ModelBuilder!



Variables and raster layers

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Activity: Raster Data – Spatial Analyst Extension

For your task:

What raster data did you have (from last week!)?

Think of an example of when & how you might use the raster calculator

Raster Data: Spatial Analyst Extension

Map Algebra

Spatial Analyst Toolbox

- Map Algebra Toolset (incl. Raster Calculator)
- Extraction Toolset
- Overlay Toolset
- Distance Toolset
- Surface Toolset

Image Classification

Raster Data: Spatial Analyst Extension

Extraction toolset

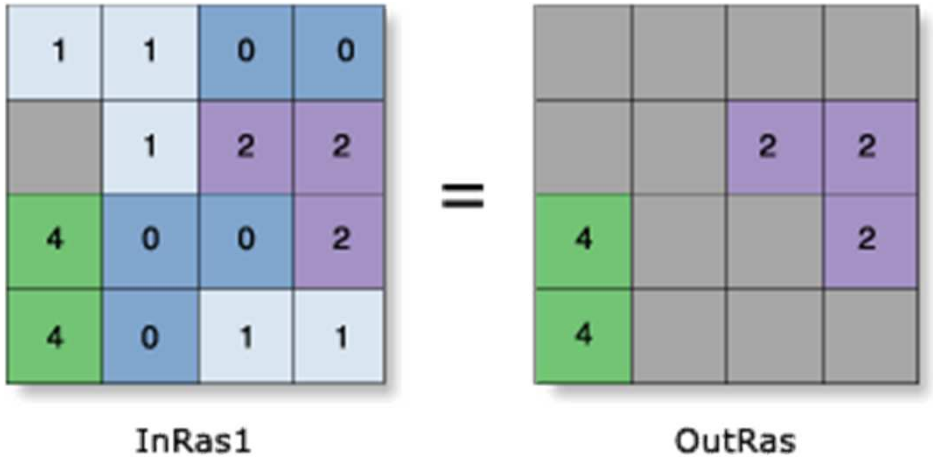
- Extract by Attributes
- Extract by Circle
- Extract by Mask
- Extract by Points
- Extract by Polygon
- Extract by Rectangle
- Extract Multi Values to Points
- Extract Values to Points
- Sample

Raster Data: Spatial Analyst Extension

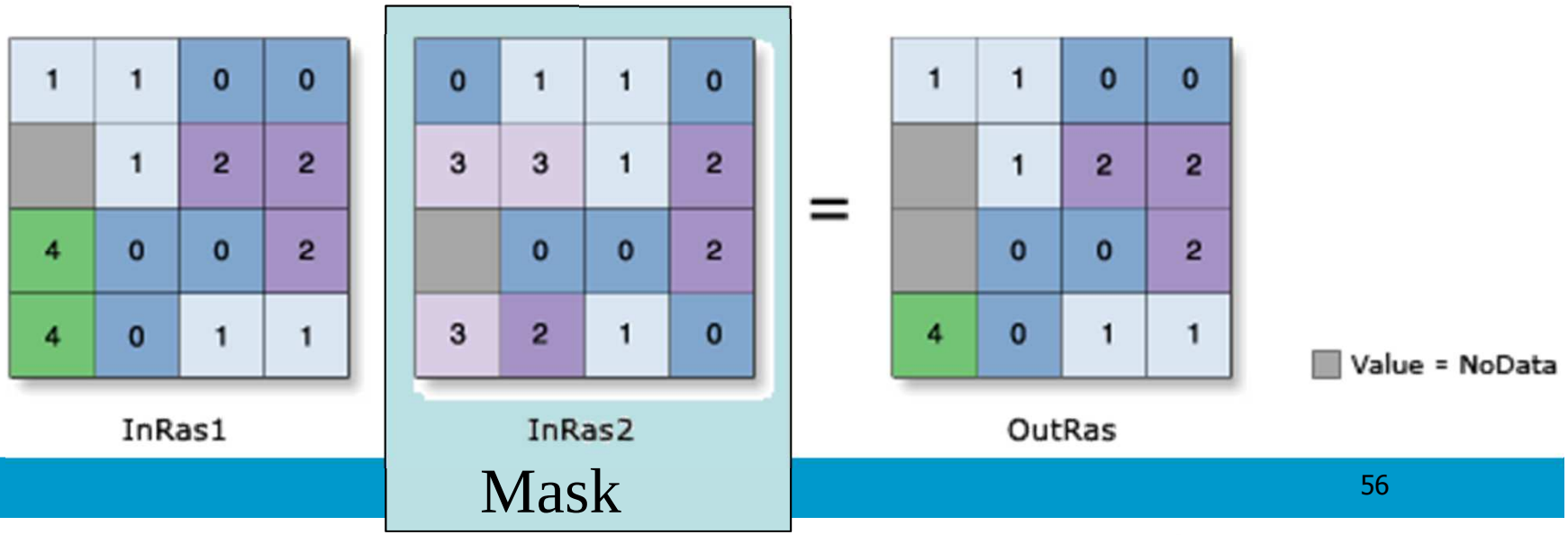
Extraction toolset

Extract by attributes

OutRas = Select(InRas1, "Value >= 2")



Extract by Mask



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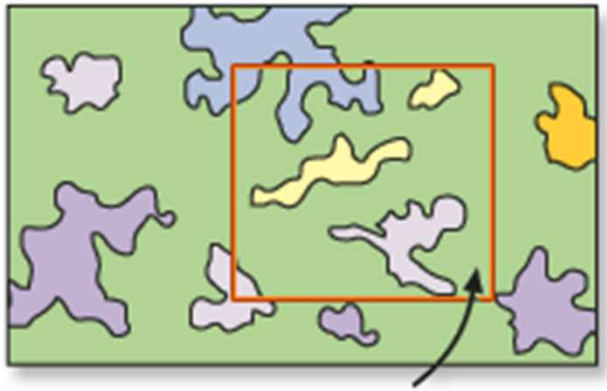
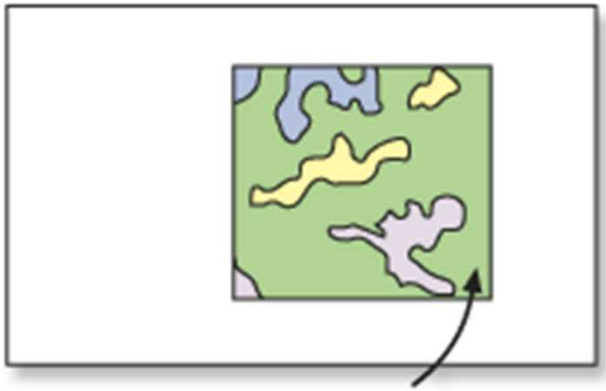
Raster Data: Spatial Analyst Extension

Extraction toolset

Extract by Rectangle

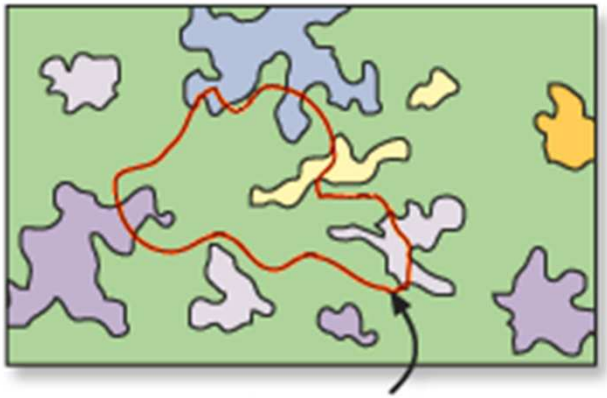


Specified rectangle



Selected cells for processing within the analysis window

Extract by Polygon



Specified polygon

Selected cells for processing within the analysis window

Raster Data: Spatial Analyst Extension

Overlay toolset

Raster overlay by addition:

INPUT 1

3	3	1
4	2	2
3	1	1

+

INPUT 2

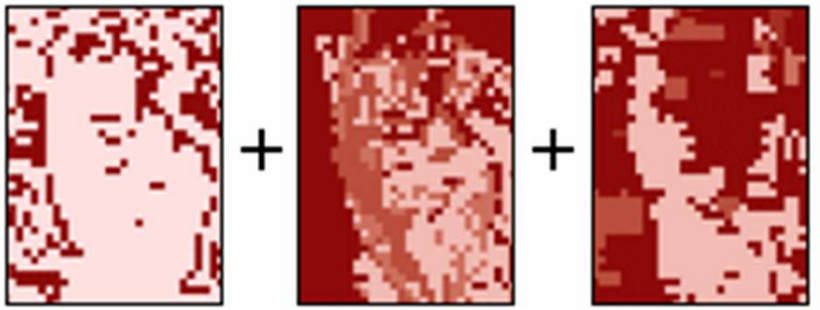
11	12	10
12	12	10
14	12	11

OUTPUT

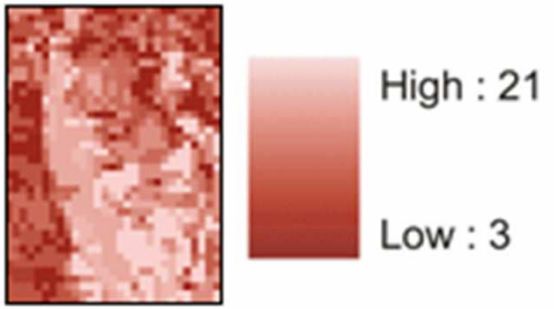
14	15	11
16	14	12
17	13	12

Raster overlay by addition for Suitability modeling

Steep slope? + Soil type + Vegetation



=



Suitability ranking

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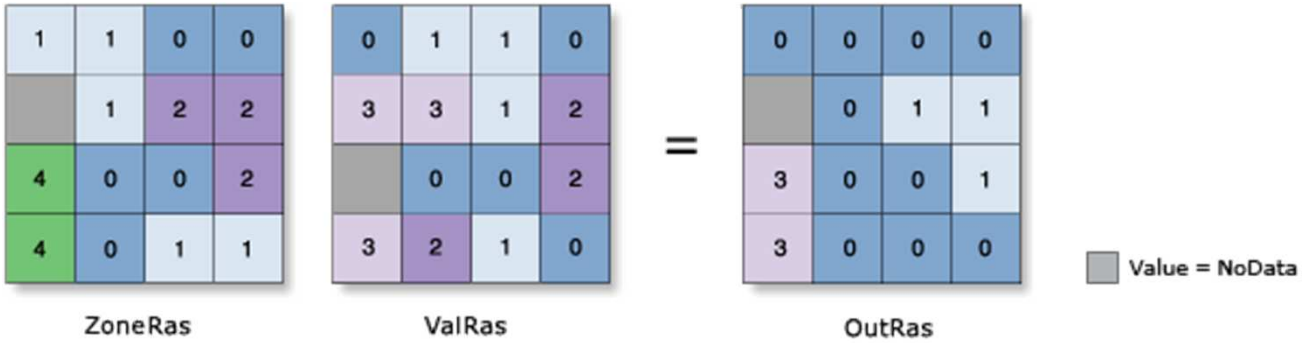
Raster Data: Spatial Analyst Extension

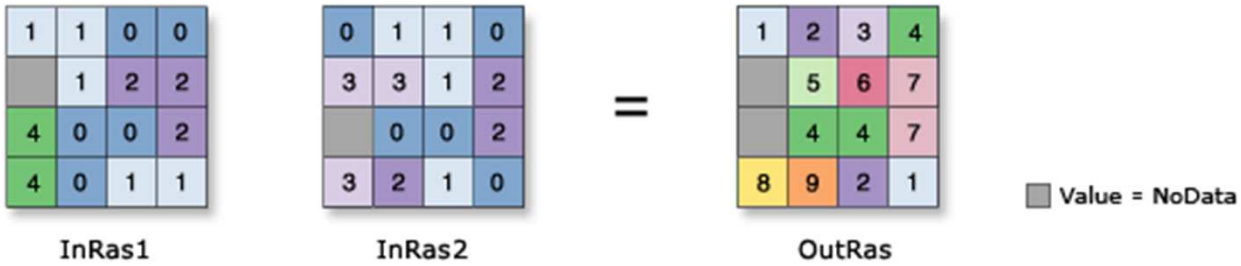
Overlay toolset

Zonal statistics

OutRas = ZonalStatistics(ZoneRas, "VALUE", ValRas, "MINIMUM")



Combine



Value	Count	Code
0	5	002
1	5	004
2	3	005
4	2	008

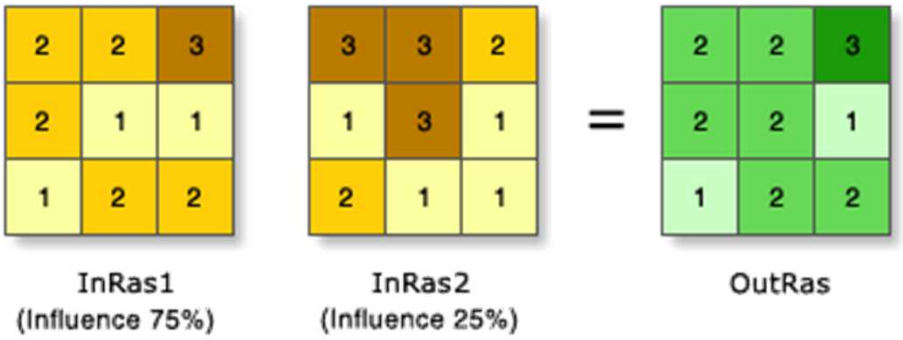
Value	Count	Type
0	5	PAX
1	4	HAR
2	3	WIN
3	3	SAN

Value	Count	InRas1	InRas2
1	2	1	0
2	2	1	1
3	1	0	1
4	3	0	0
5	1	1	3
6	1	2	1
7	2	2	2
8	1	4	3
9	1	0	2

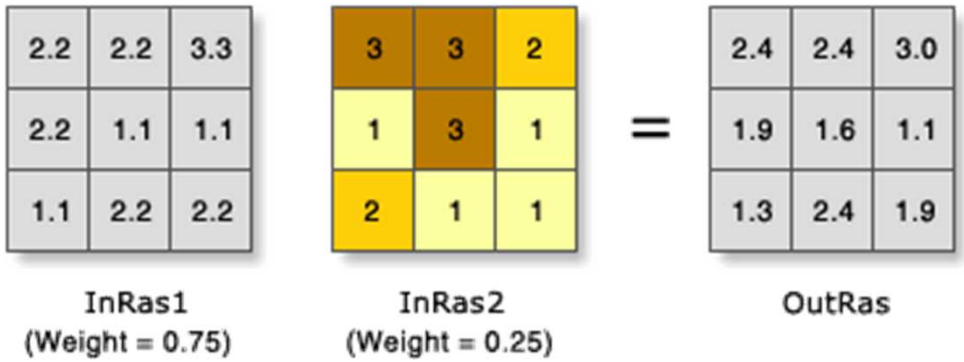
Raster Data: Spatial Analyst Extension

Overlay toolset

Weighted overlay
(all integers)



Weighted sum
(Integer or float)



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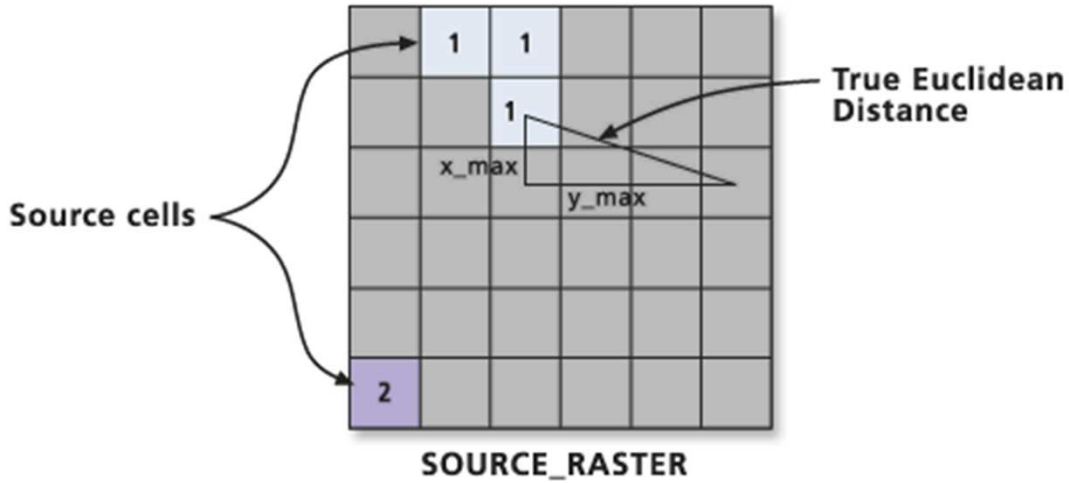
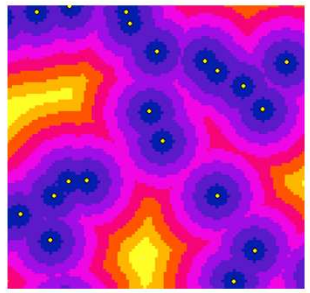
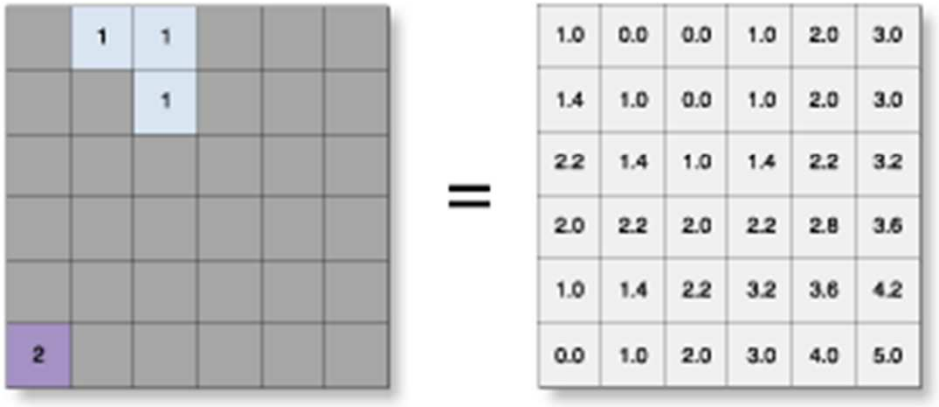
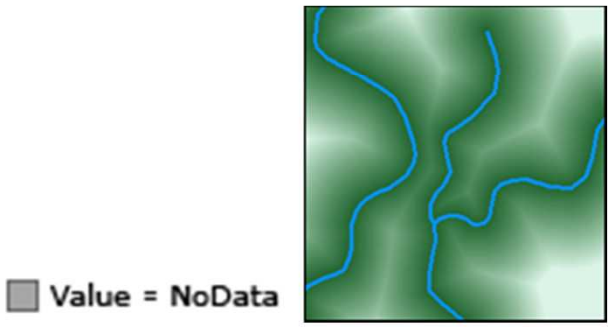
Raster Data: Spatial Analyst Extension

Distance toolset: Euclidean Distance









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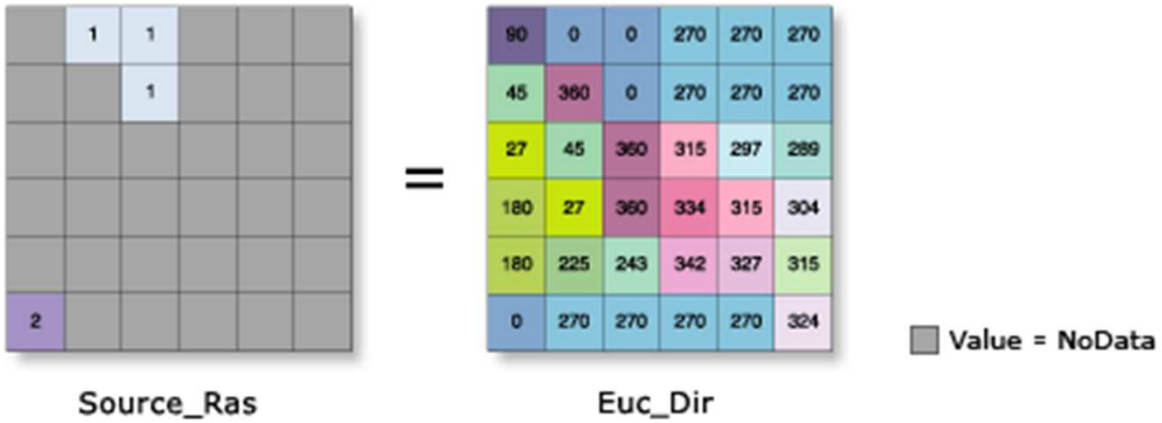
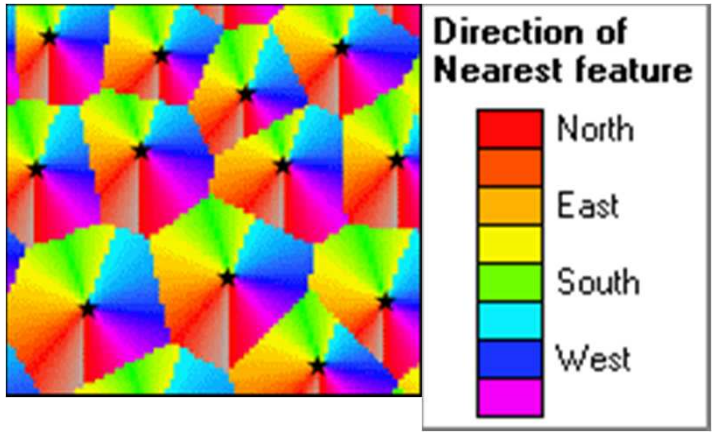
Raster Data: Spatial Analyst Extension

Distance toolset: Euclidean Direction



Point input feature



Map showing the direction of the nearest town for each location

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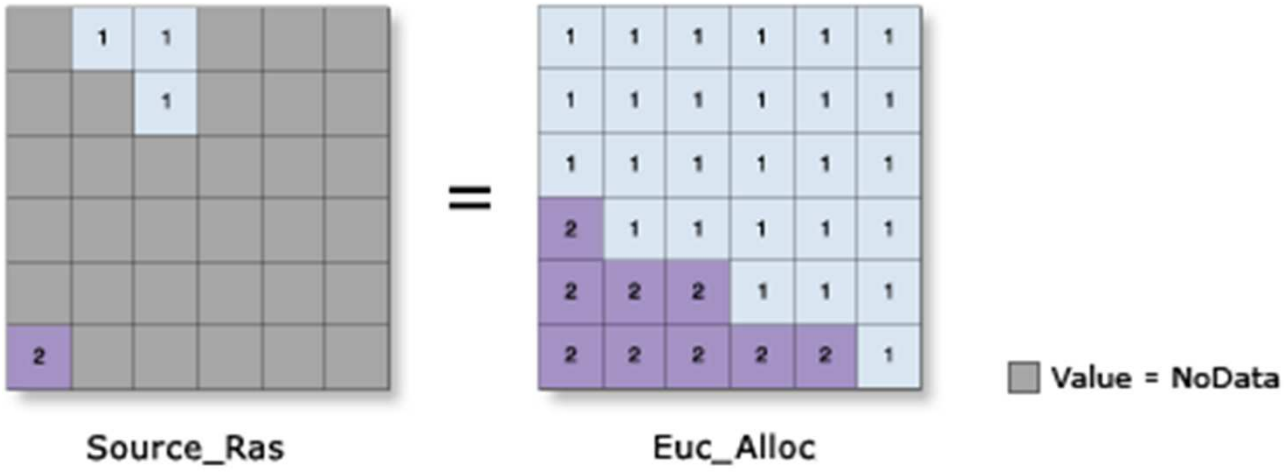
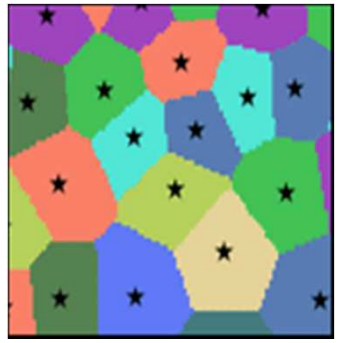
Raster Data: Spatial Analyst Extension

Distance toolset: Euclidean Allocation



Compare to Thiessen polygons!



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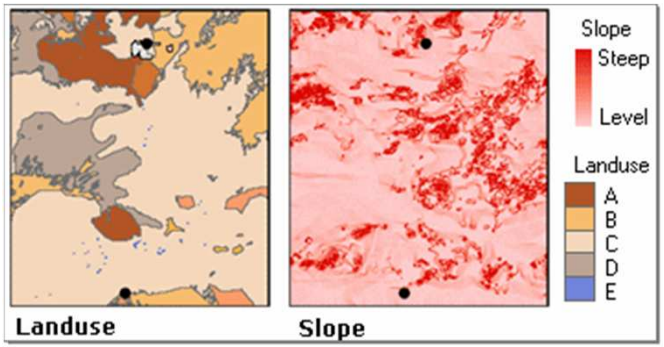
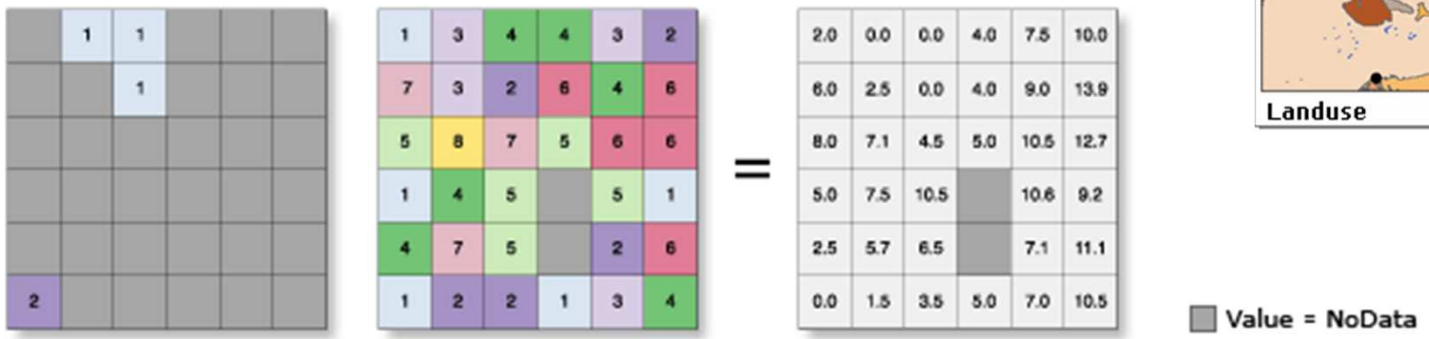
Raster Data: Spatial Analyst Extension

Distance toolset: Cost Distance





Cost_Dist = CostDistance(Source_Ras, Cost_Ras)

The cost distance tool calculates the least accumulative cost distance for each cell to the nearest source over a cost surface.

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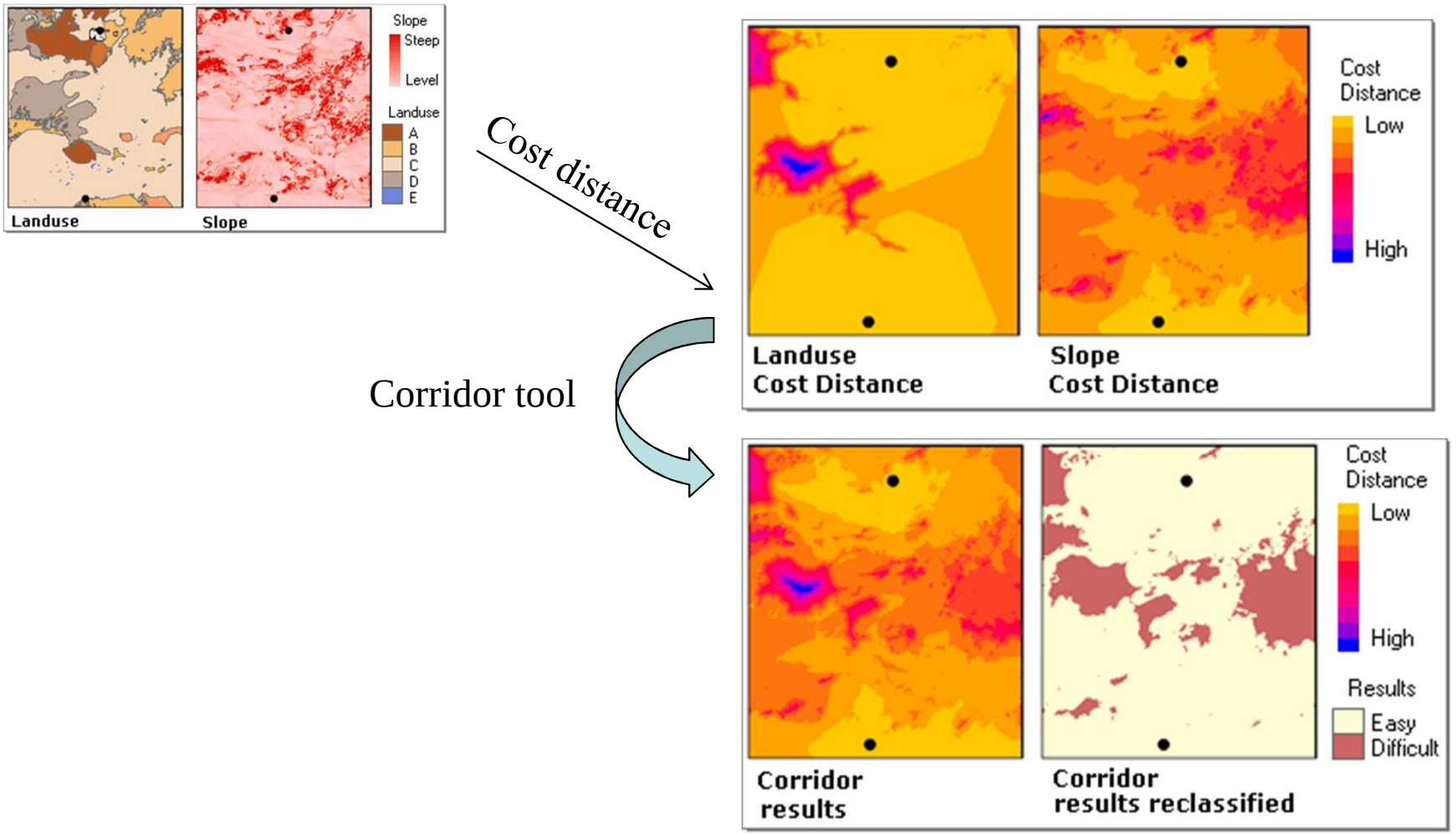
Raster Data: Spatial Analyst Extension

Distance toolset: Cost Distance



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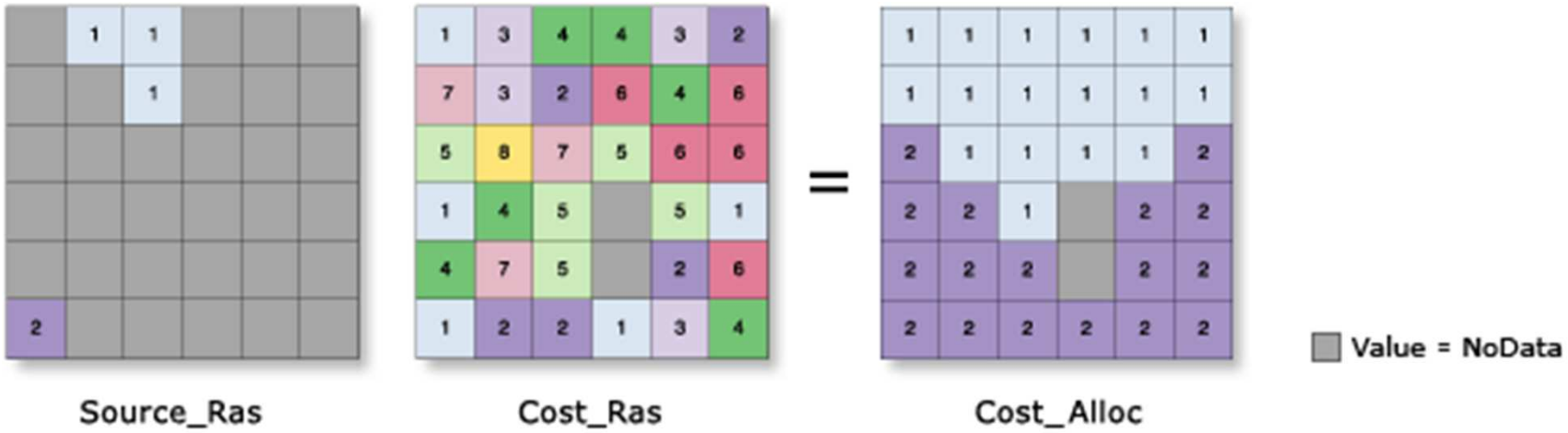
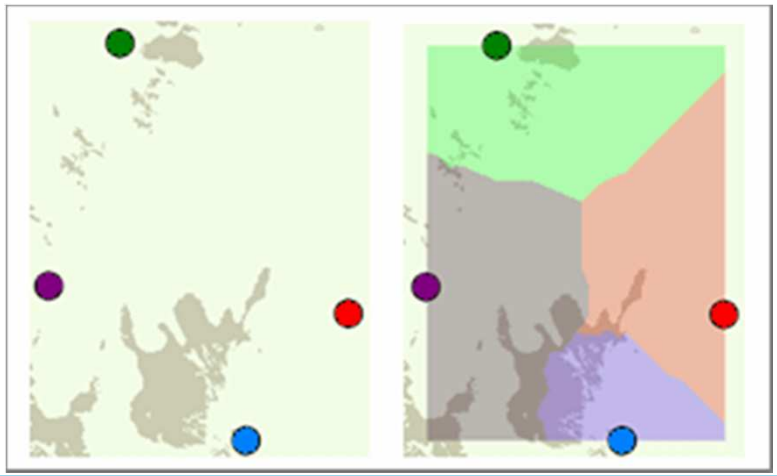
Raster Data: Spatial Analyst Extension

Distance toolset: Cost Allocation





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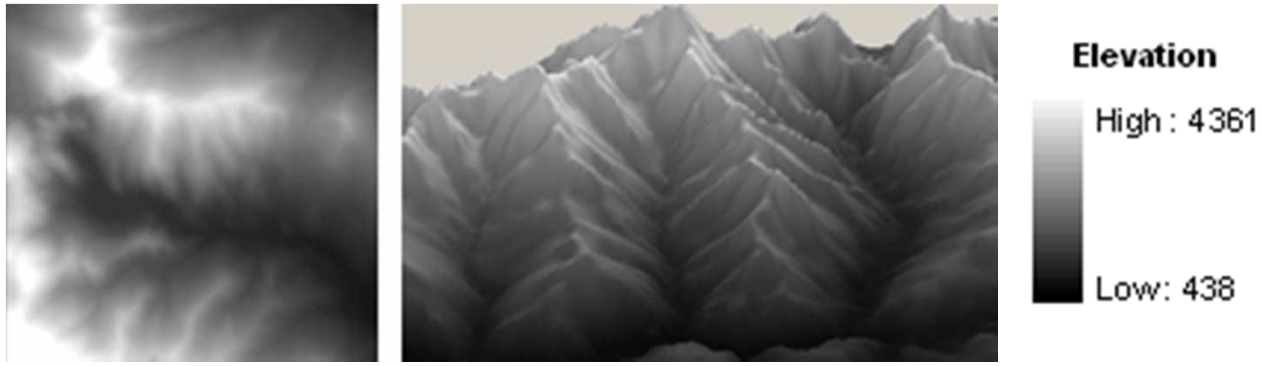
Raster Data: Spatial Analyst Extension

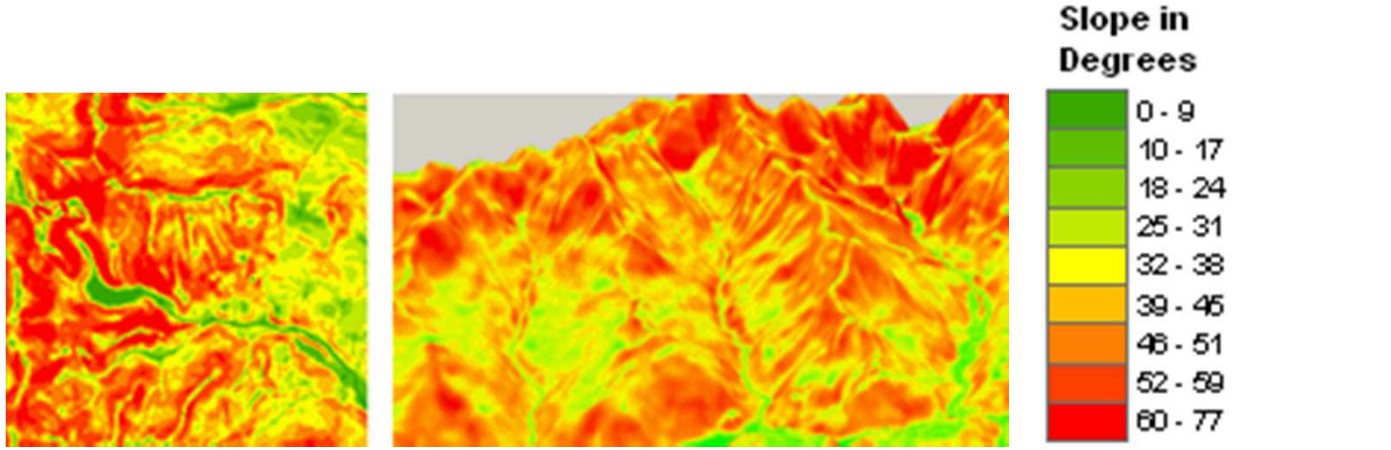
Surface toolset:

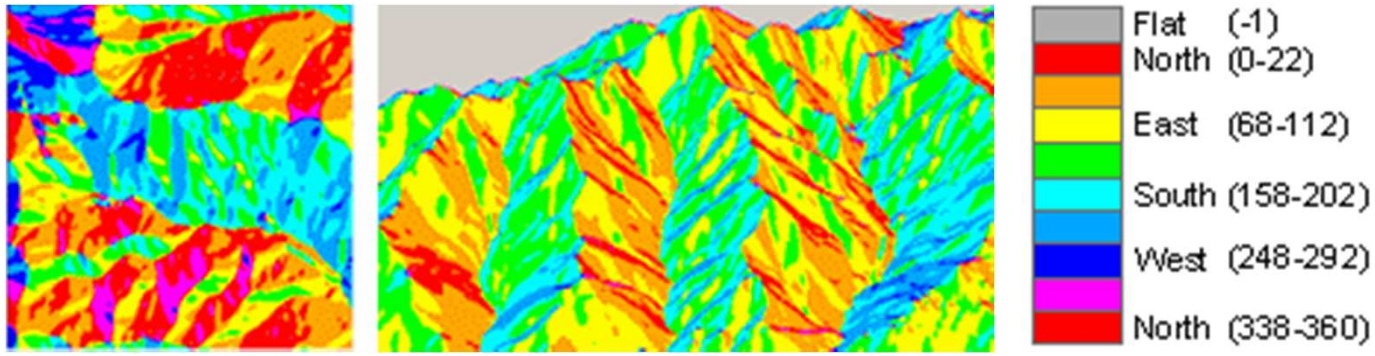


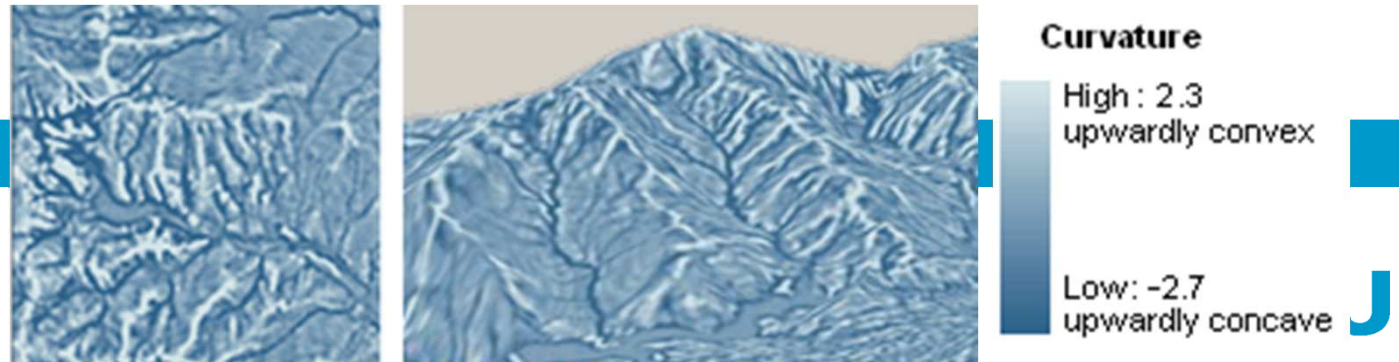
Surface characteristics
Terrain relief & visualization
Visibility Analysis
Create contours
Volumetric analysis

Raster Data: Spatial Analyst Extension

Surface toolset: Surface Characteristics







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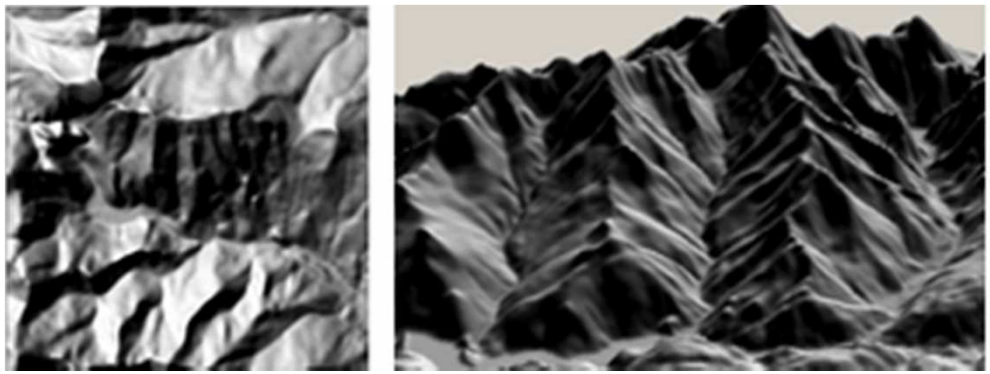
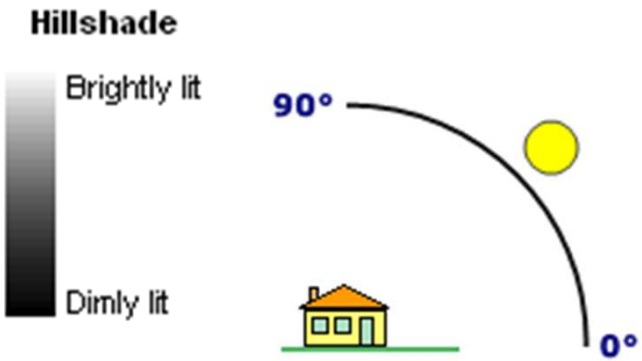
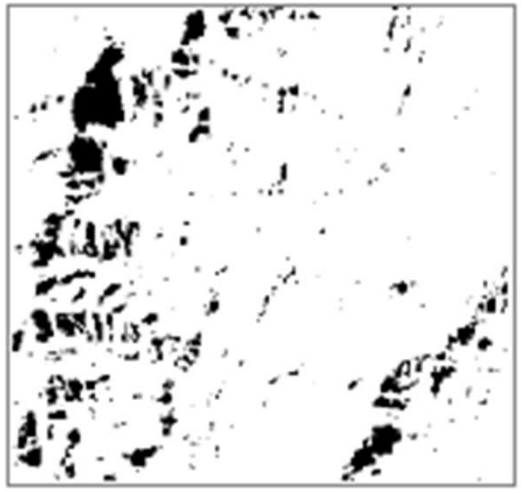
Raster Data: Spatial Analyst Extension

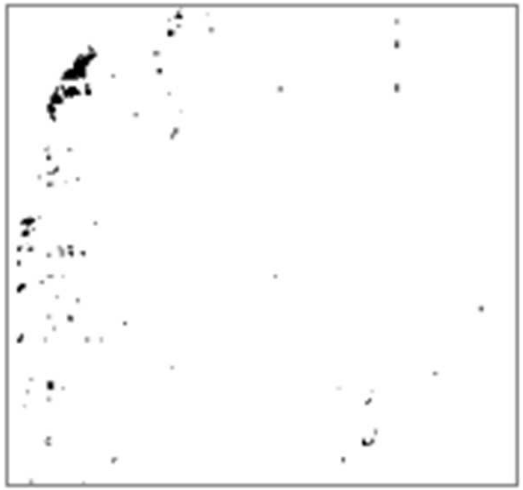
Surface toolset: Terrain Relief & Visualization





Shadows with low sun angle





Shadows with high sun angle

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Raster Data: Spatial Analyst Extension

Surface toolset: Visibility Analysis

Observer points

Viewshed

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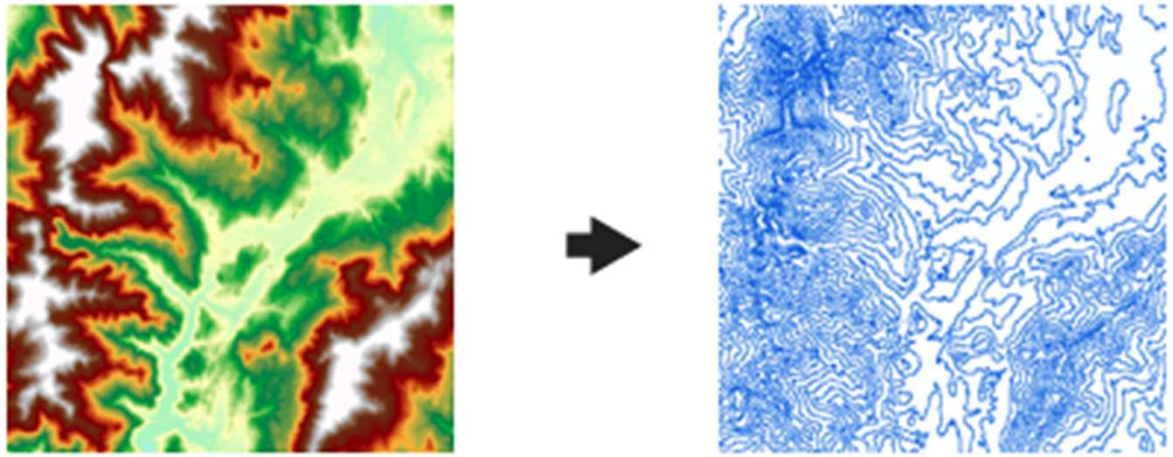
Raster Data: Spatial Analyst Extension

Surface toolset: Create Contours



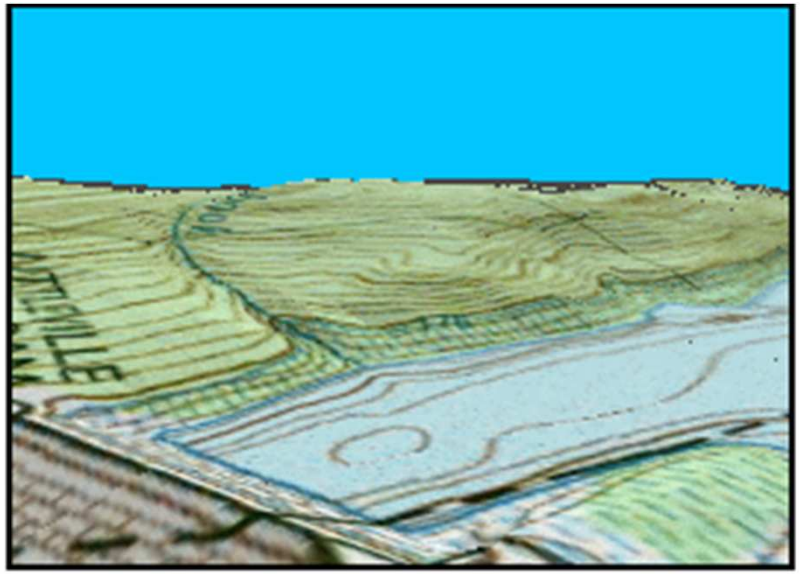
Input elevation raster

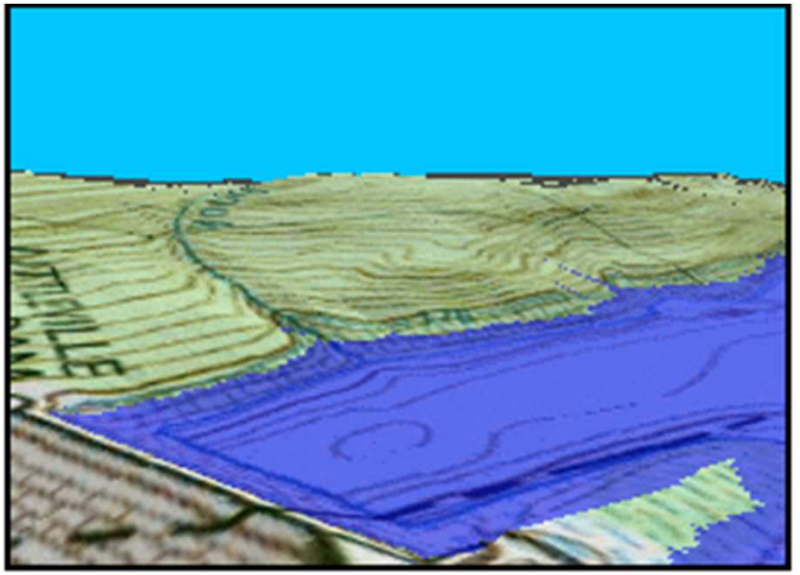
Output contours

Tools: Contour
Contour List
Contour With Barriers

Raster Data: Spatial Analyst Extension

Surface toolset: Volumetric Analysis





Tools: Surface Volume
Cut Fill

Activity: Raster Data – Spatial Analyst Extension

For your task:

What raster data did you have (from last week!)?

Think of an example of when & how you might use one of the toolsets:

- **Overlay**
- **Extraction**
- **Distance (Euclidean or cost)**
- **Surface Analysis**

Raster Data: Spatial Analyst Extension

Image Classification Toolbar

Multiband raster dataset

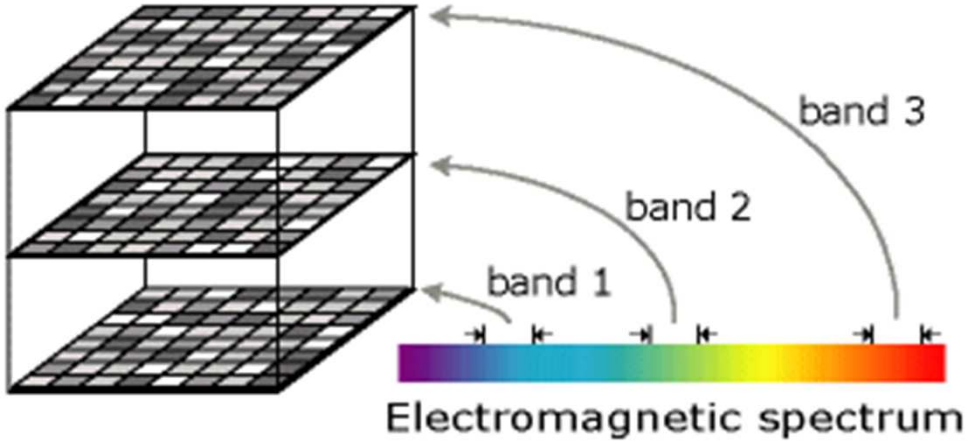
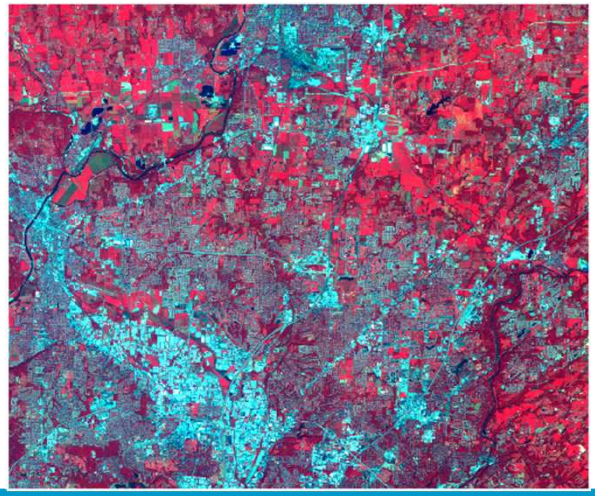


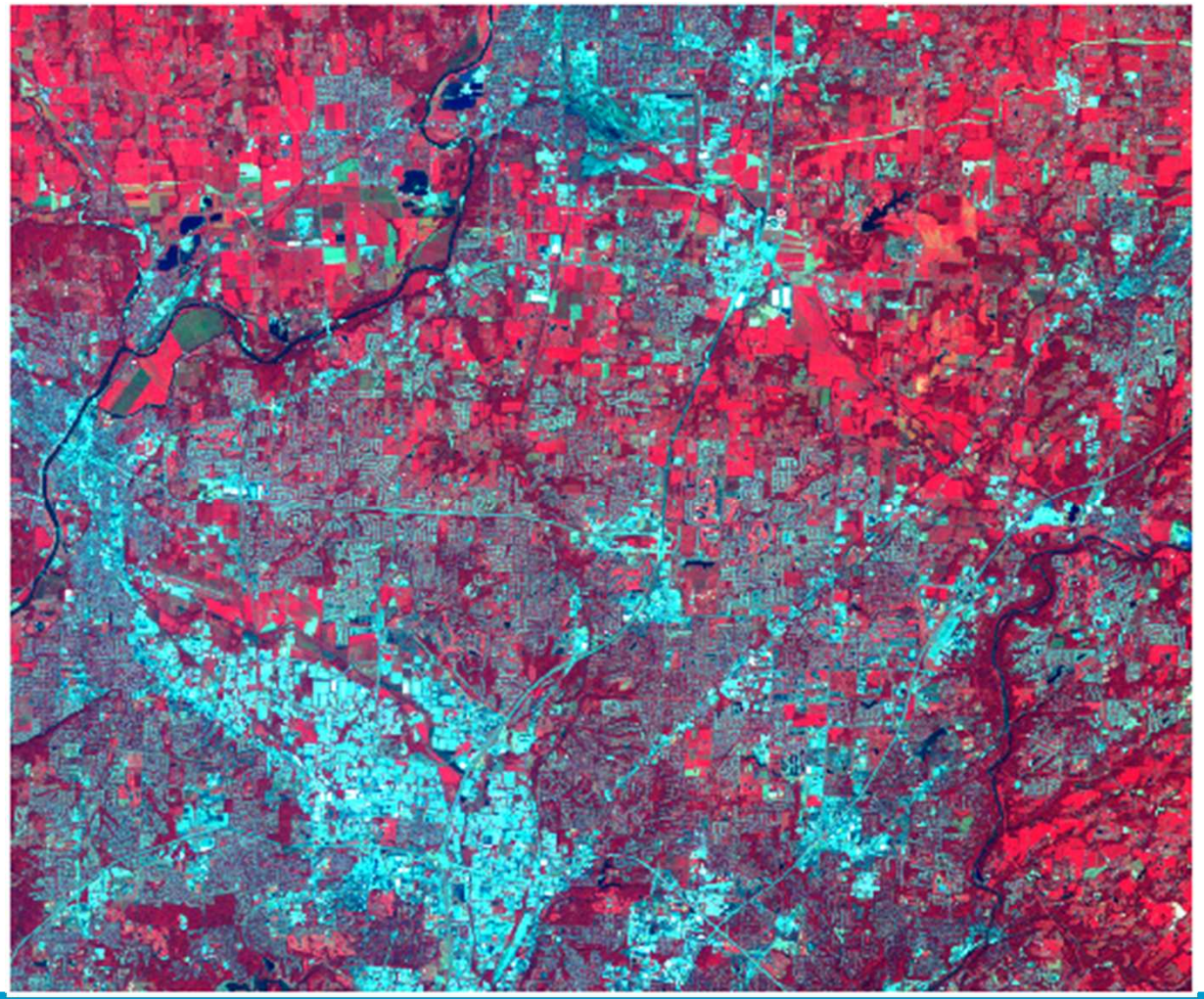
Image classification:
Identify the commercial, industrial and agricultural areas.



Raster Data: Spatial Analyst Extension

Image Classification Toolbar

Input
Landsat TM
image



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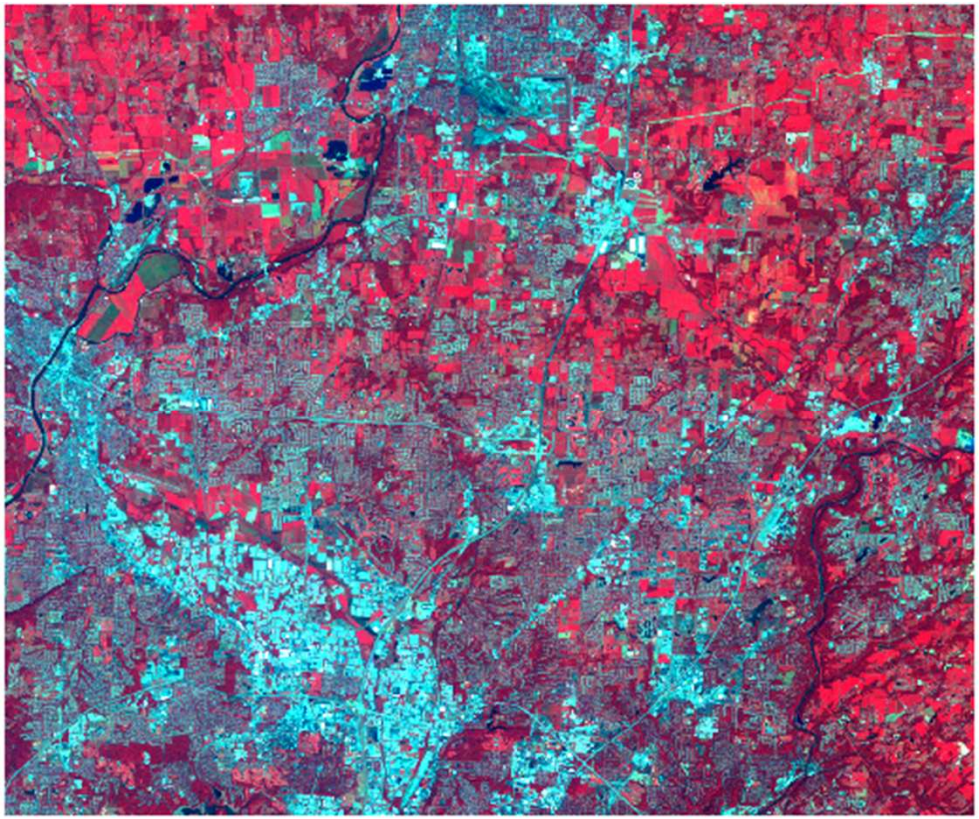
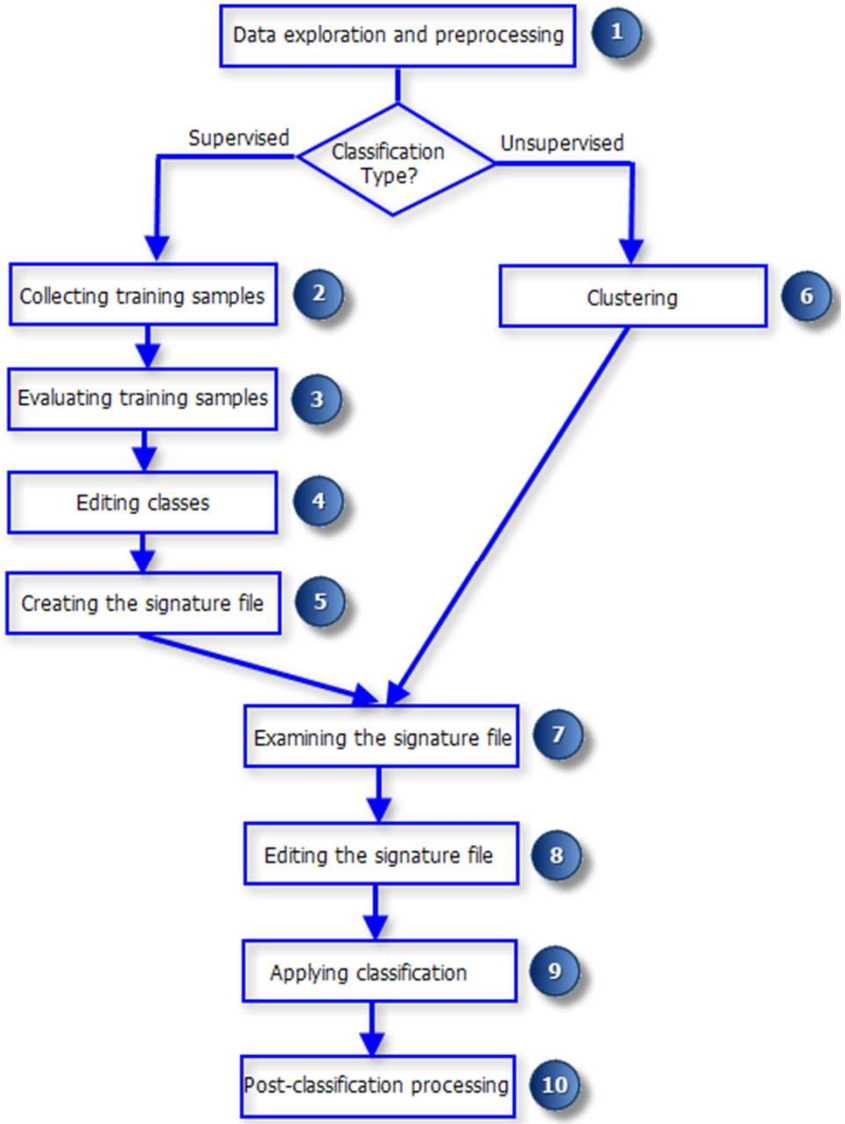
Raster Data: Spatial Analyst Extension

Image Classification Toolbar





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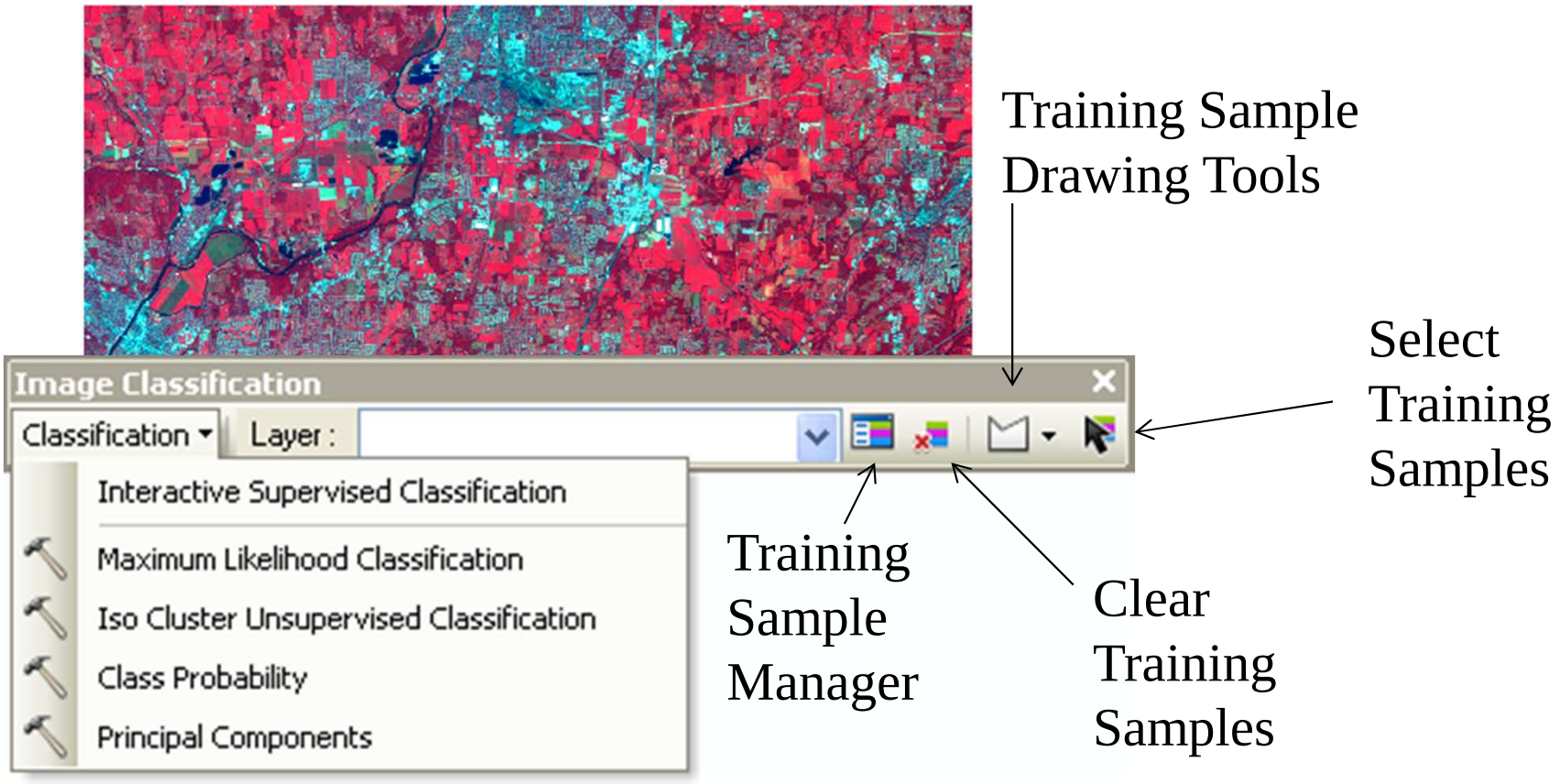
Raster Data: Spatial Analyst Extension

Image Classification Toolbar

ArcMap: Customize> Toolbars> Image Classification



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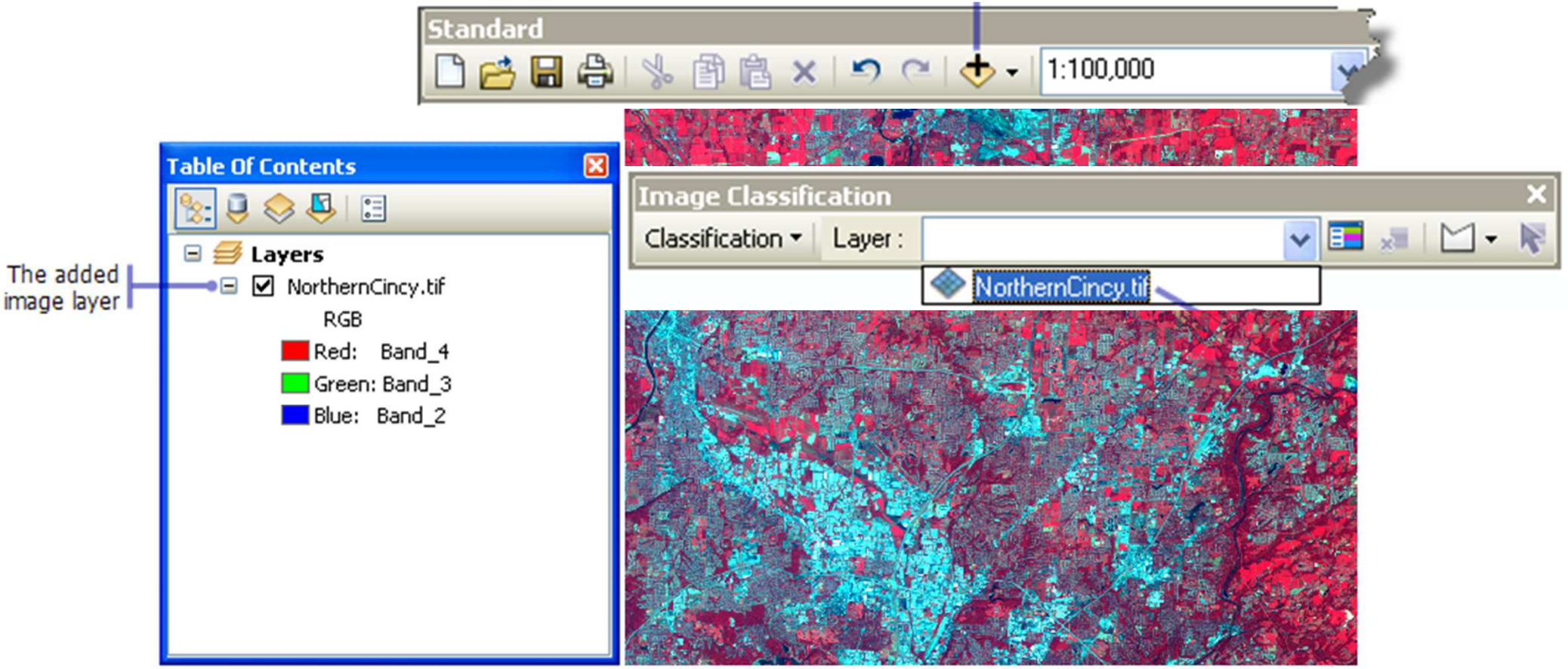
Raster Data: Spatial Analyst Extension

Image Classification Toolbar:

Adding Multiband image for classification



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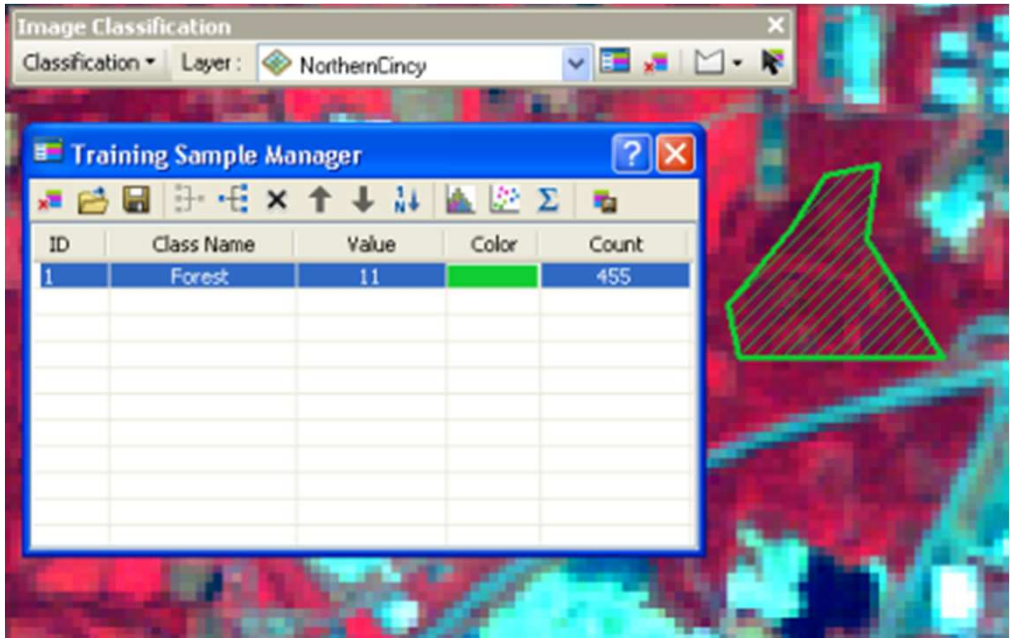
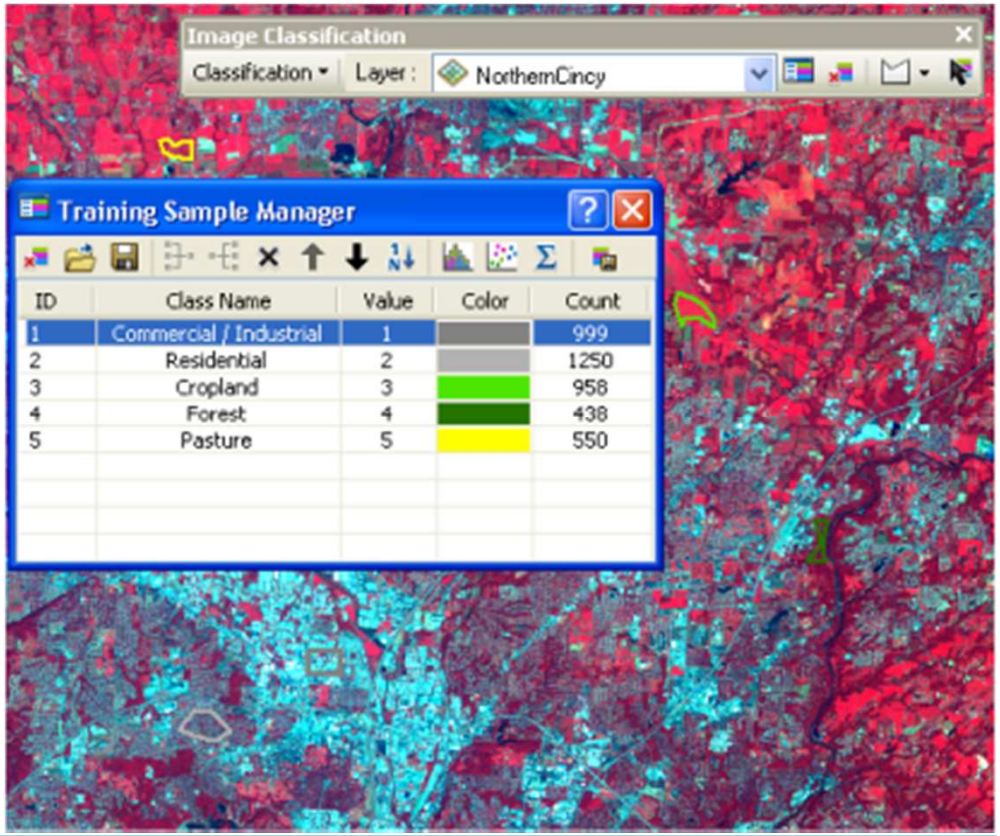
Raster Data: Spatial Analyst Extension

Image Classification Toolbar:
Create Training Samples





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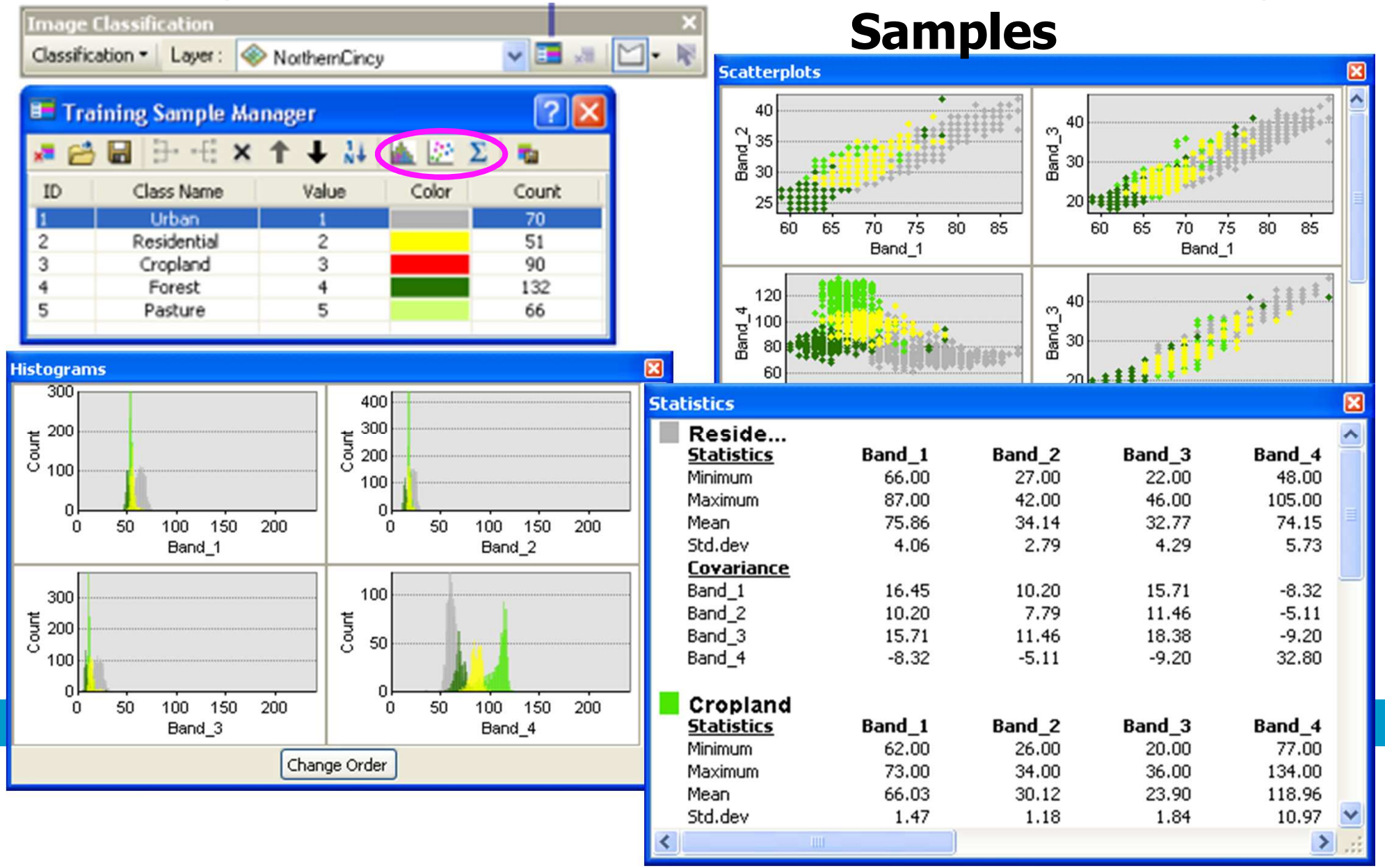
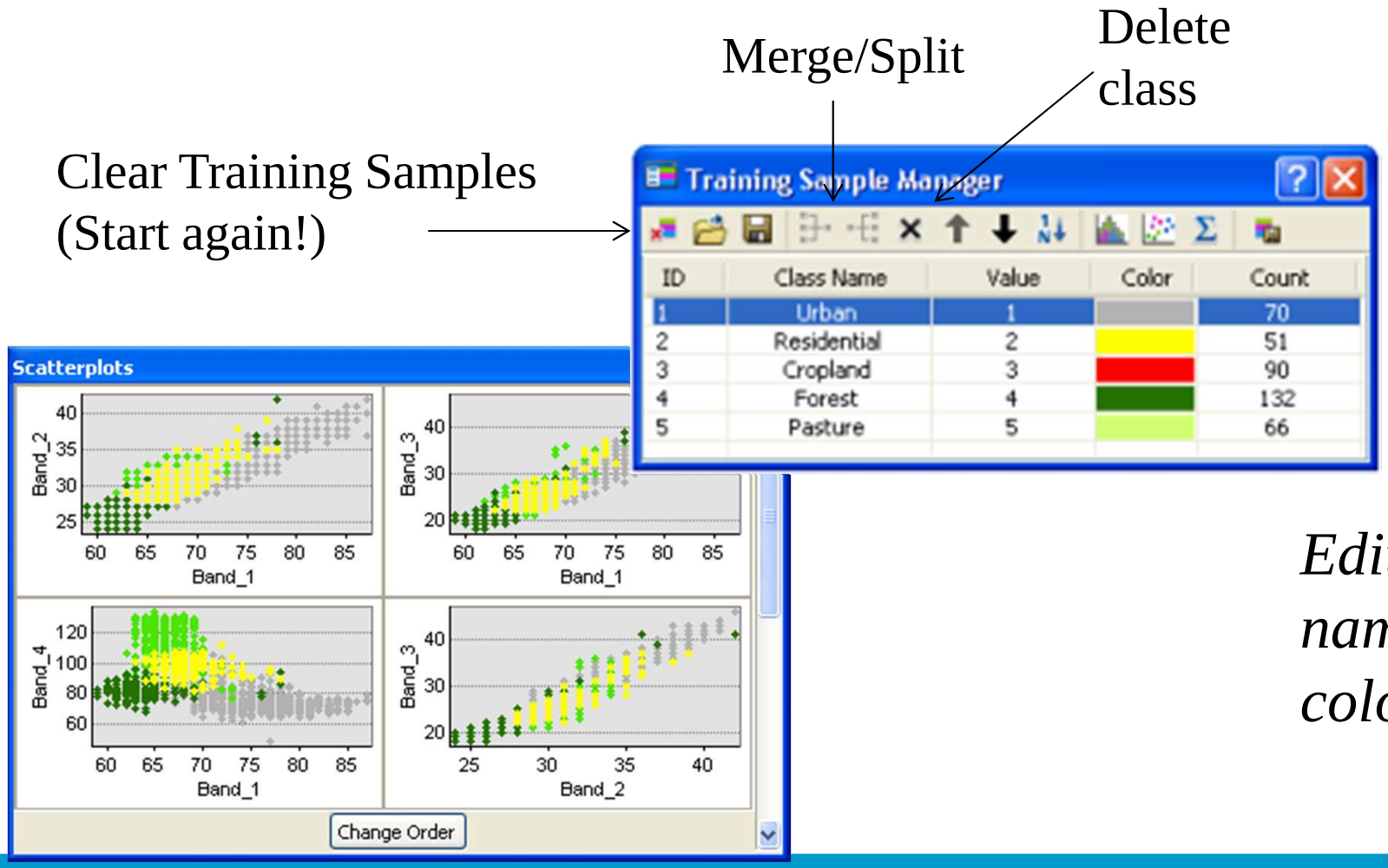
Raster Data: Spatial Analyst Extension

Image Classification Toolbar: Evaluate Training Samples



Raster Data: Spatial Analyst Extension

Image Classification Toolbar



Edit class names, display color etc..

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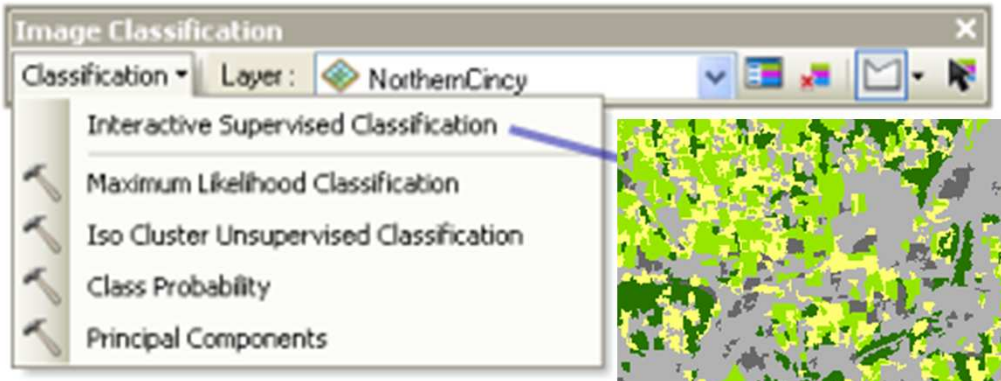
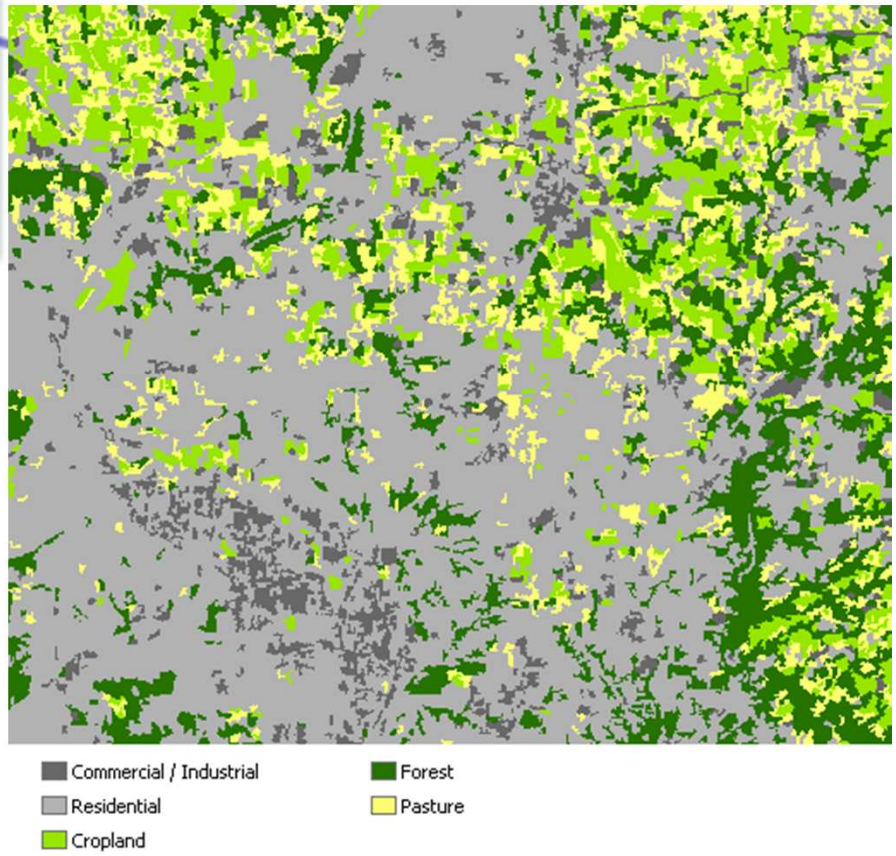
Raster Data: Spatial Analyst Extension

Image Classification Toolbar



Output classified land use map



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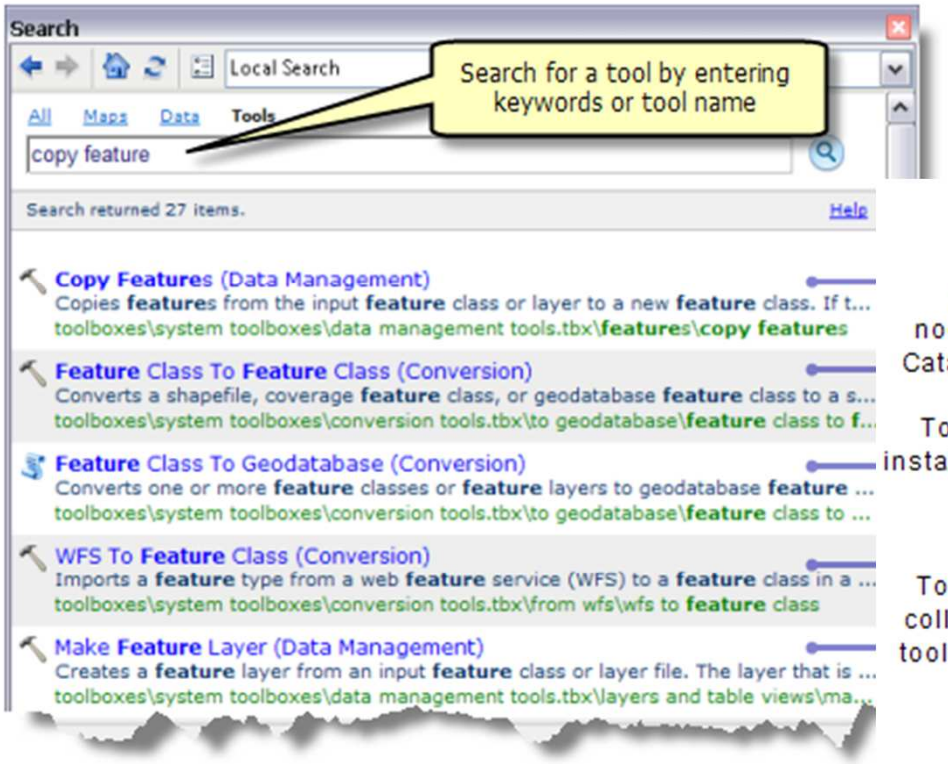
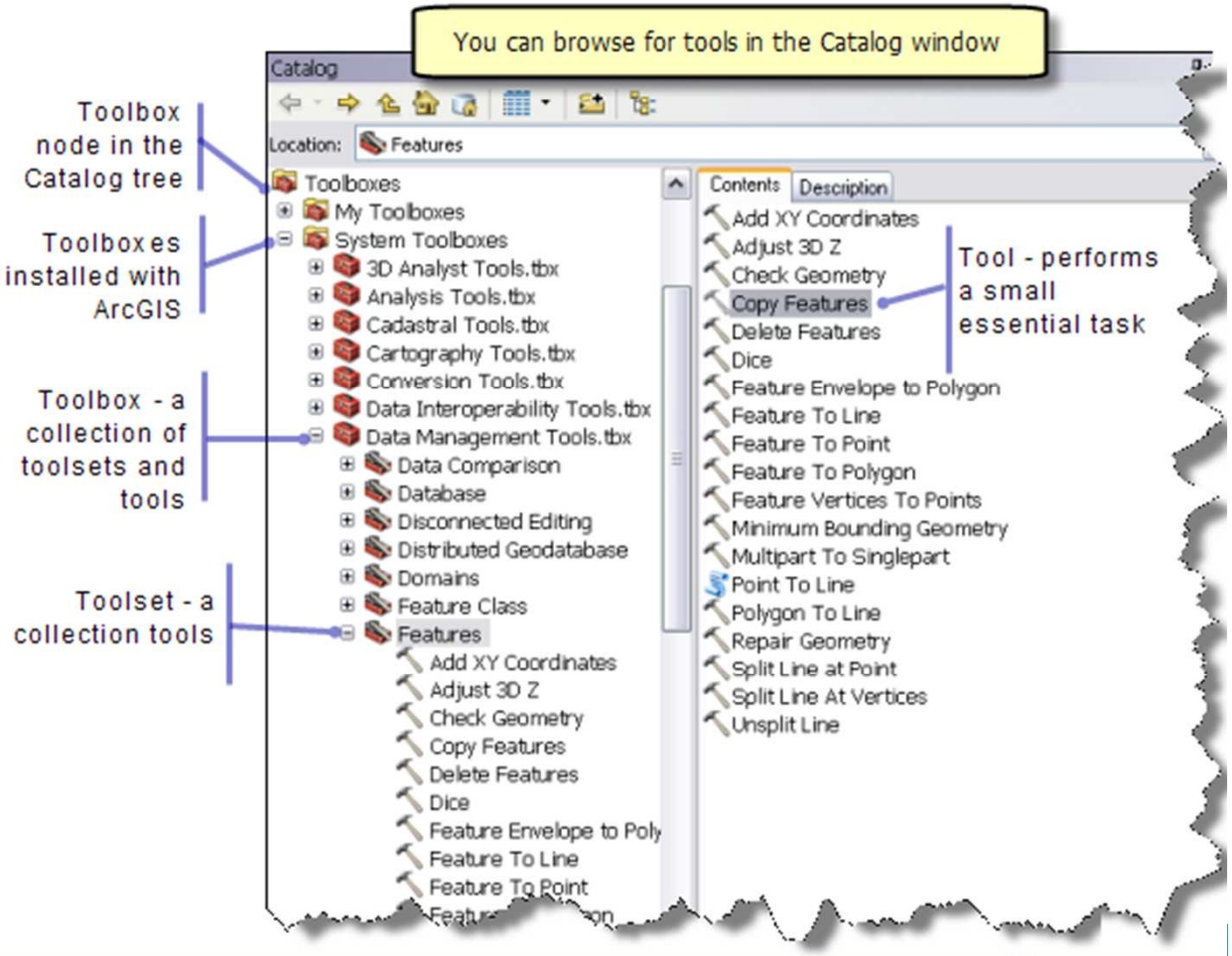
Lecture outline

- Review Lecture 1 & Assignment 1
- Geoprocessing
- Feature data: Analysis Toolbox
- Raster data: Spatial Analyst Extension
- Geoprocessing framework
- Introduction to Assignment 2

Geoprocessing framework



Work directly with tools



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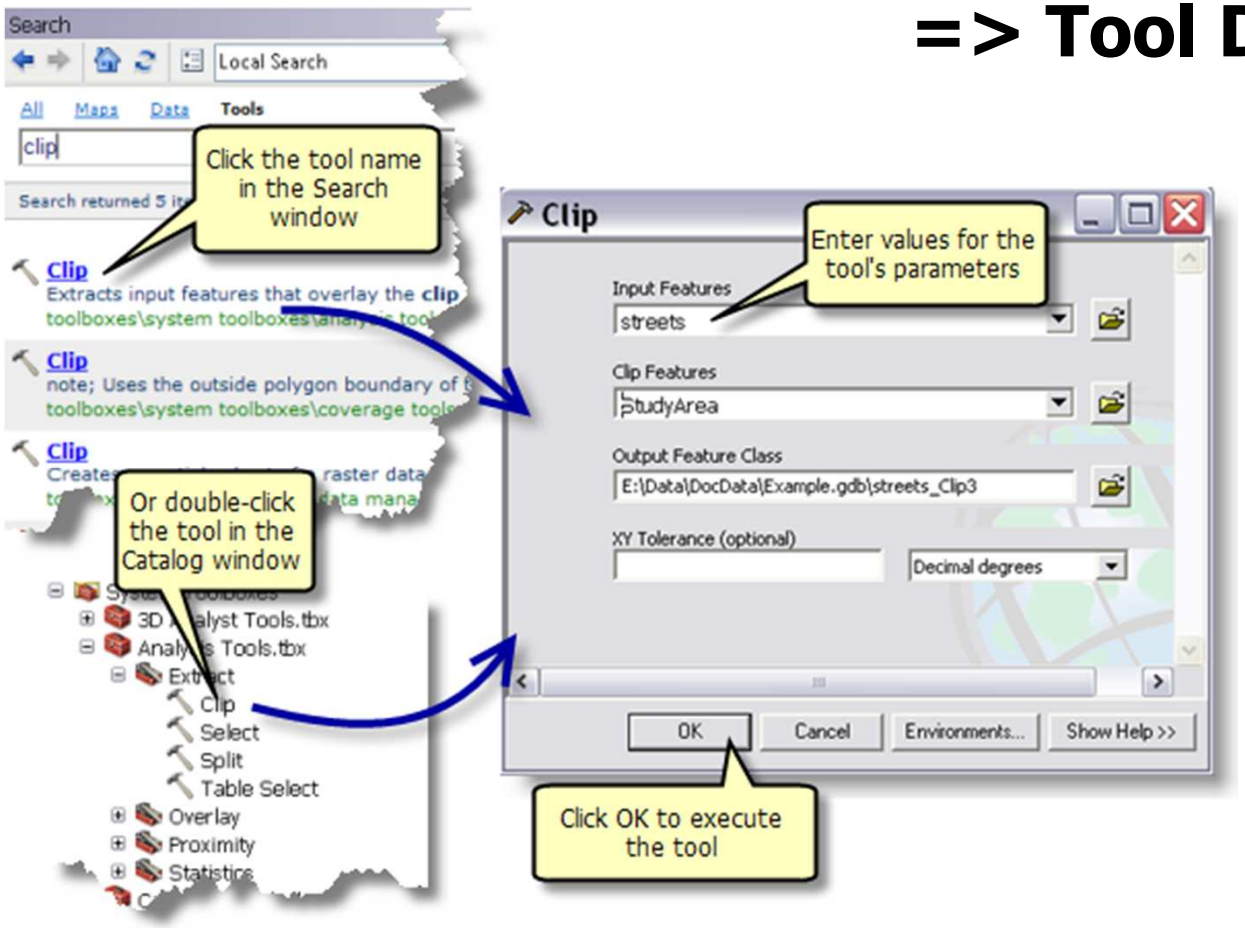
Geoprocessing framework

Work directly with tools
=> Tool Dialog box



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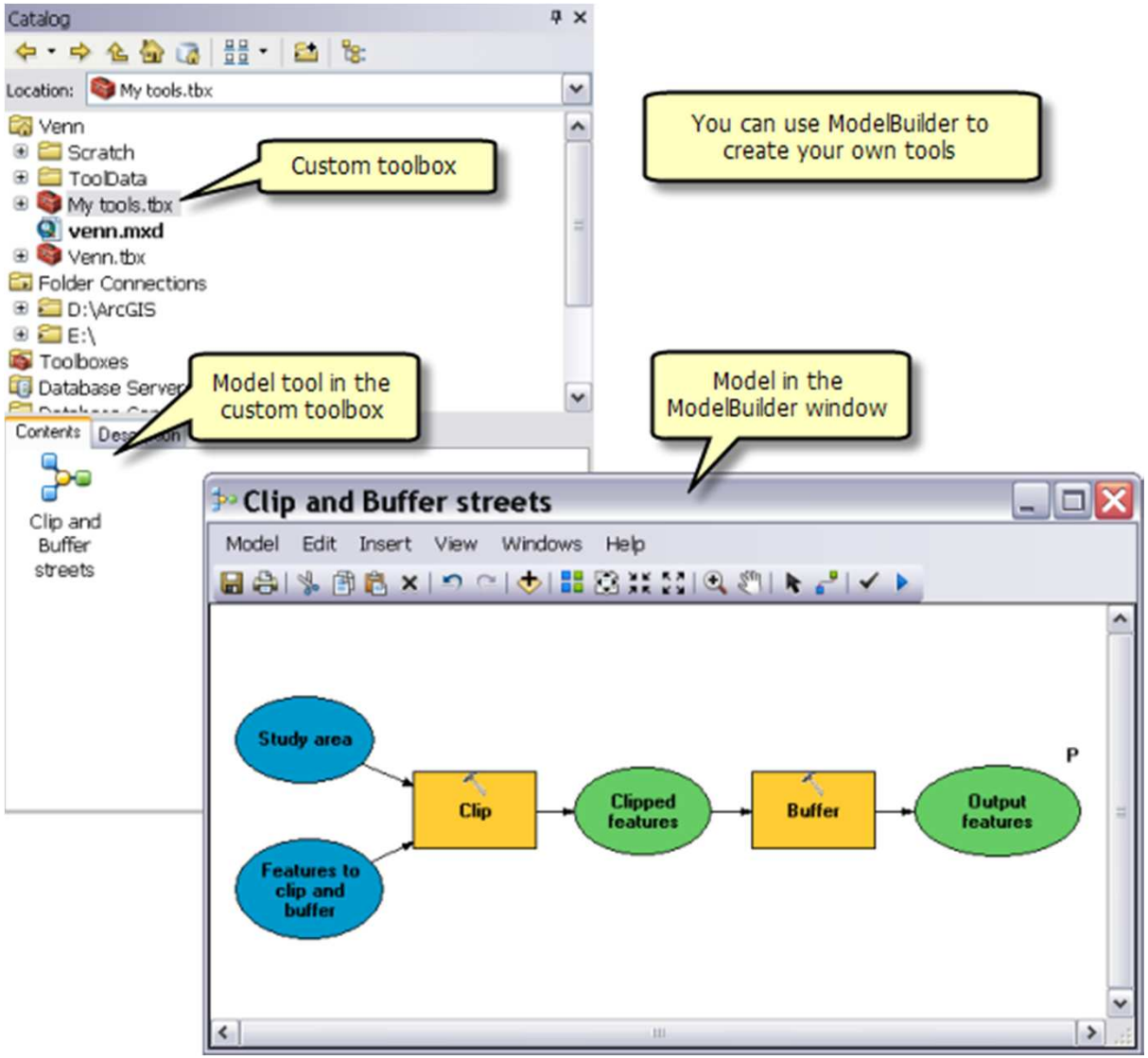
Geoprocessing framework



Models and ModelBuilder

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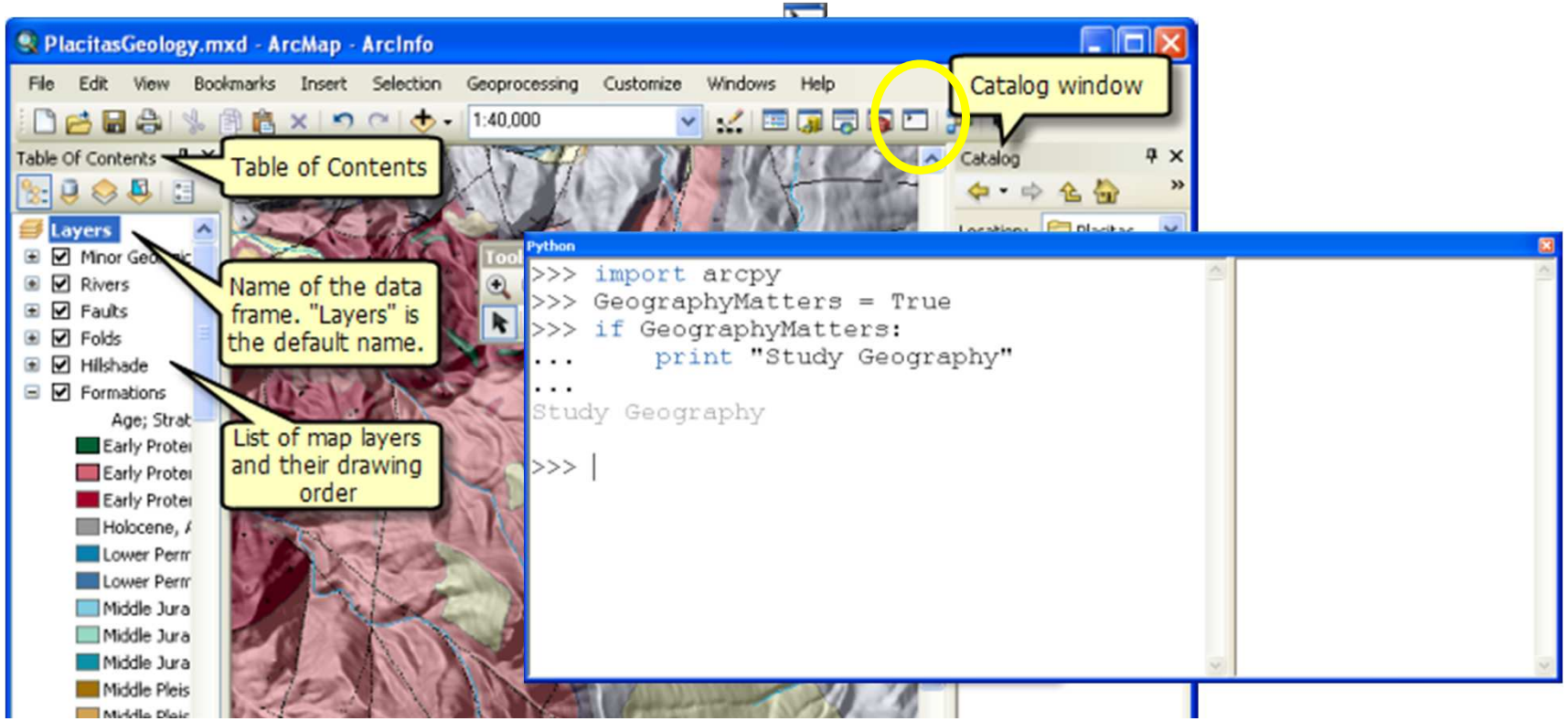
Geoprocessing framework

Python Window




```
>>> arcpy.ImportToolbox("c:/mytools/geometrytools.tbx")
>>> arcpy.CreateRegularPolygons_geometry(
```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Geoprocessing framework

Python Scripting

```
# Name: Slope
# Description: Identifies the rate of maximum change
#     in z-value from each cell.
# Requirements: Spatial Analyst Extension
# Author: ESRI

# Import system modules
import arcpy
from arcpy import env
from arcpy.sa import *

# Set environment settings
env.workspace = "C:/data"

# Set local variables
inRaster = "elevation"
outMeasurement = "DEGREE"
zFactor = 0.3043

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

# Execute Slope
outSlope = Slope(inRaster, outMeasurement, zFactor)

# Save the output
outSlope.save("C:/output/outslope02")
```

Return to Lecture Outline

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- Feature data: Analysis Toolbox
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- Geoprocessing framework
- Introduction to Assignment 2

Introduction to Assignment 2

Calculate damage due to a flood in your polder

20 million m^3 water entered your polder.
You need to prepare:

1) Inundation map
2) Damage map
3) Table with damage per category

Assignment details and DEM on Blackboard

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Introduction to Assignment 2

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Sources images

All images in these lecture slides are from the ArcGIS software and from www.esri.com.