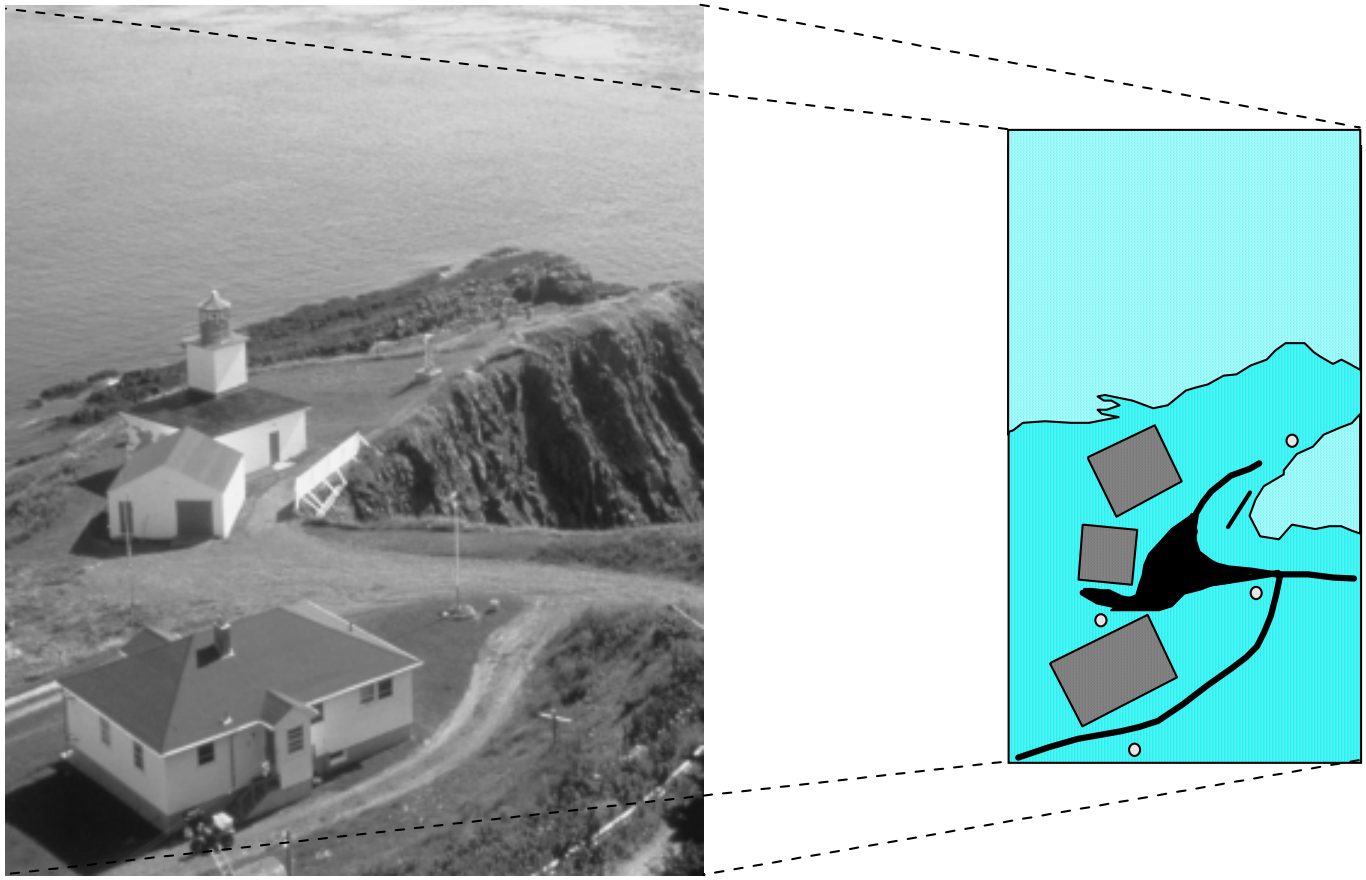
Raster Data and ArcGIS Spatial Analyst

- Raster Concepts
- Why use Raster Data?
- ArcGIS Spatial Analyst

Cartographic Abstraction

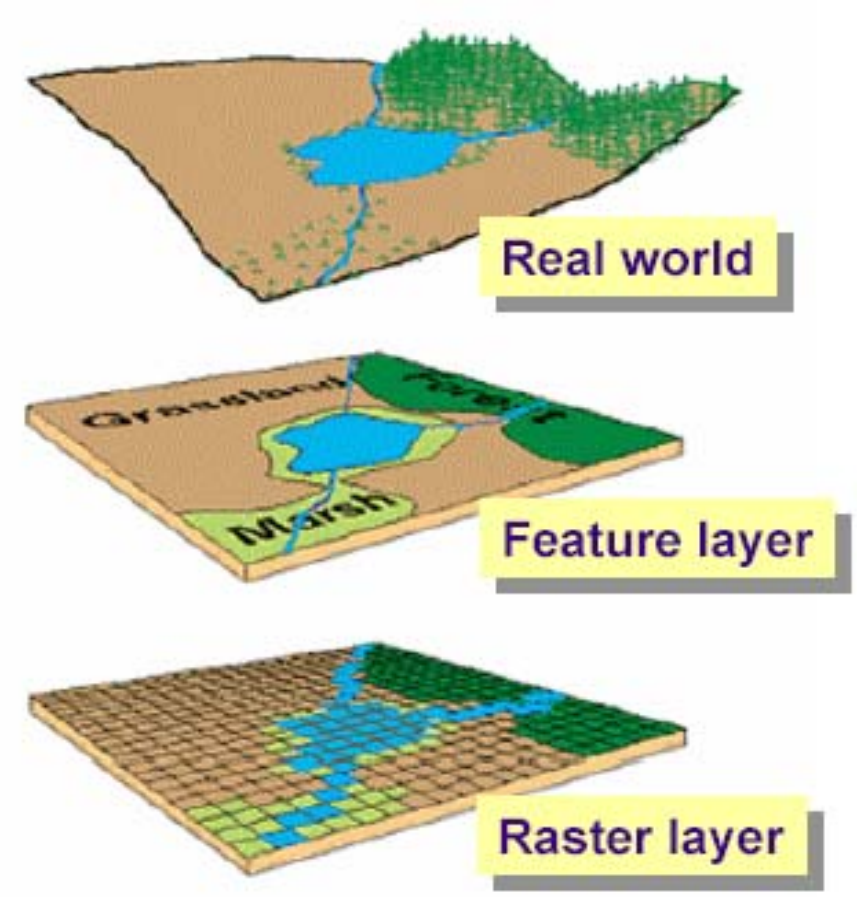
- **Tessellations**: ways of **dividing up** geographic space
- Begin by **conceptualizing and filtering** geographic reality
  - Involves a **selective** process
    - What is **important** (for the application)
    - What is to be **included**

Cartographic Abstraction



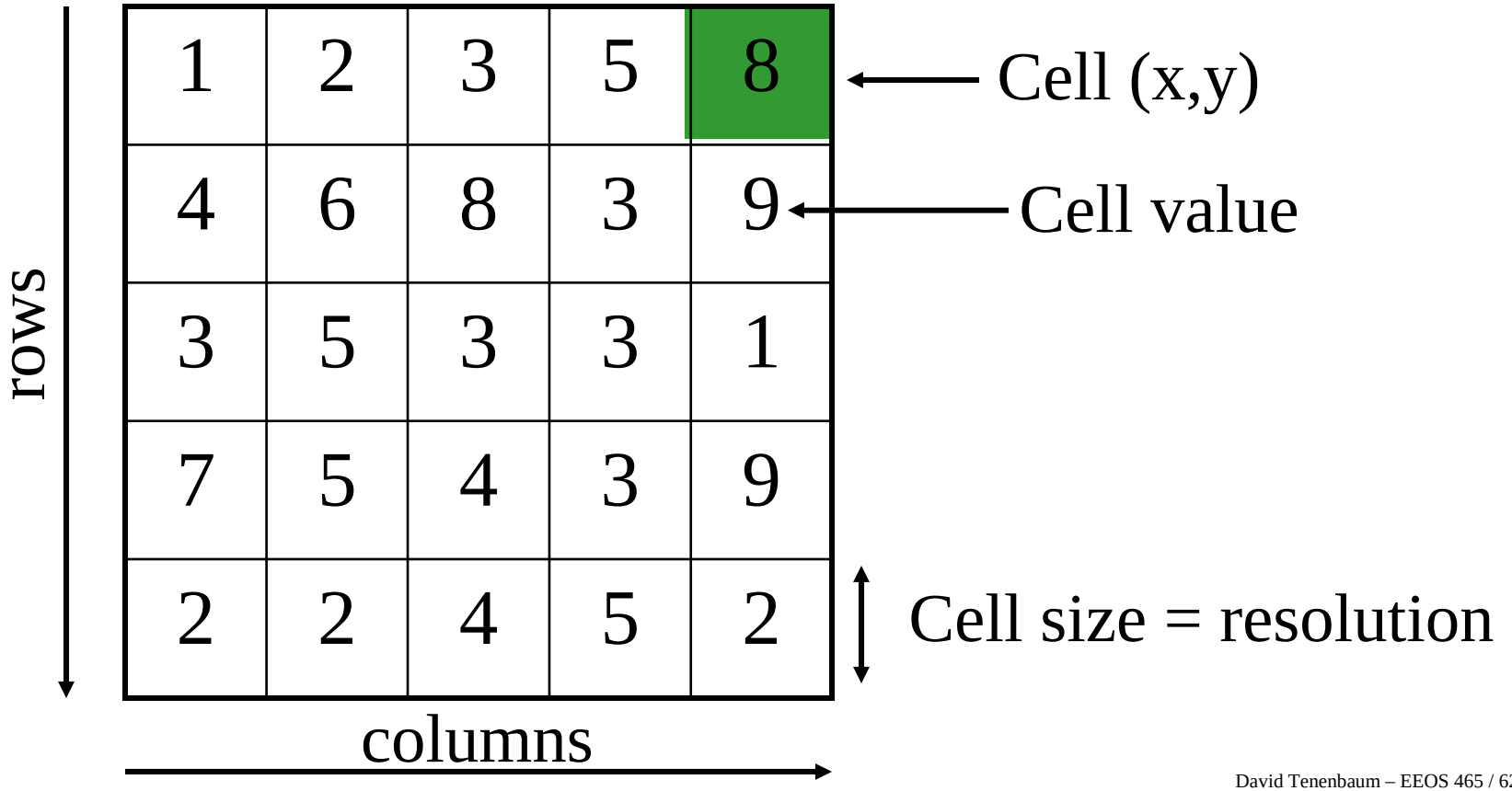
Geography as Raster

- A raster is a **matrix** of **equal-sized** cells
- These are **organized** in **rows and columns**
- Each **cell** stores a **number/value**



Raster Data Model

•The raster data model represents the Earth's surface as an **array** of two-dimensional grid cells, with each cell having an associated value:

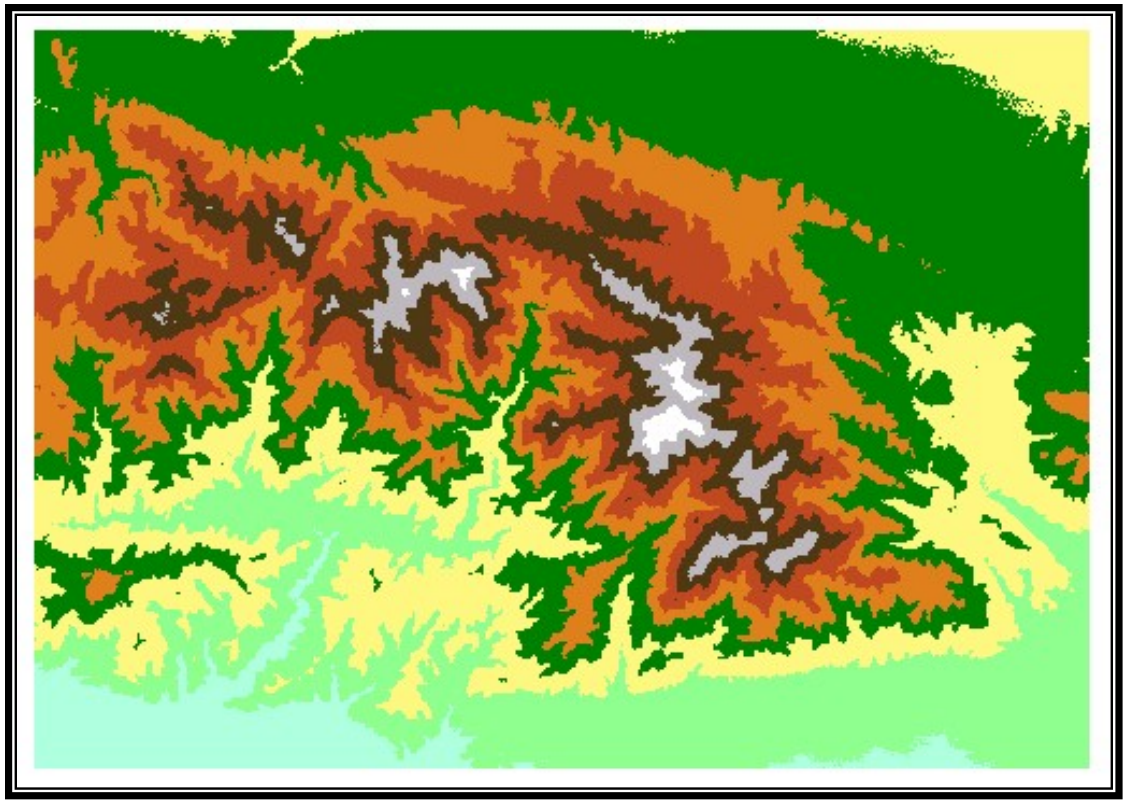


Raster Data Model

- Each grid cell in a raster data layer is one **unit** (the minimum amount of information in the raster data model)
- Every cell has a **value**, even if it is a special value to indicate that there is “no data” or that data is “missing” at that location
- The values are numbers, either:
  - **absolute values** **OR**
  - **codes** representing an **attribute**

Cells - Absolute Values

•In this instance, the **value** of the cell is actually the value of the phenomenon of interest, e.g. elevation data (whether floating point or integer):



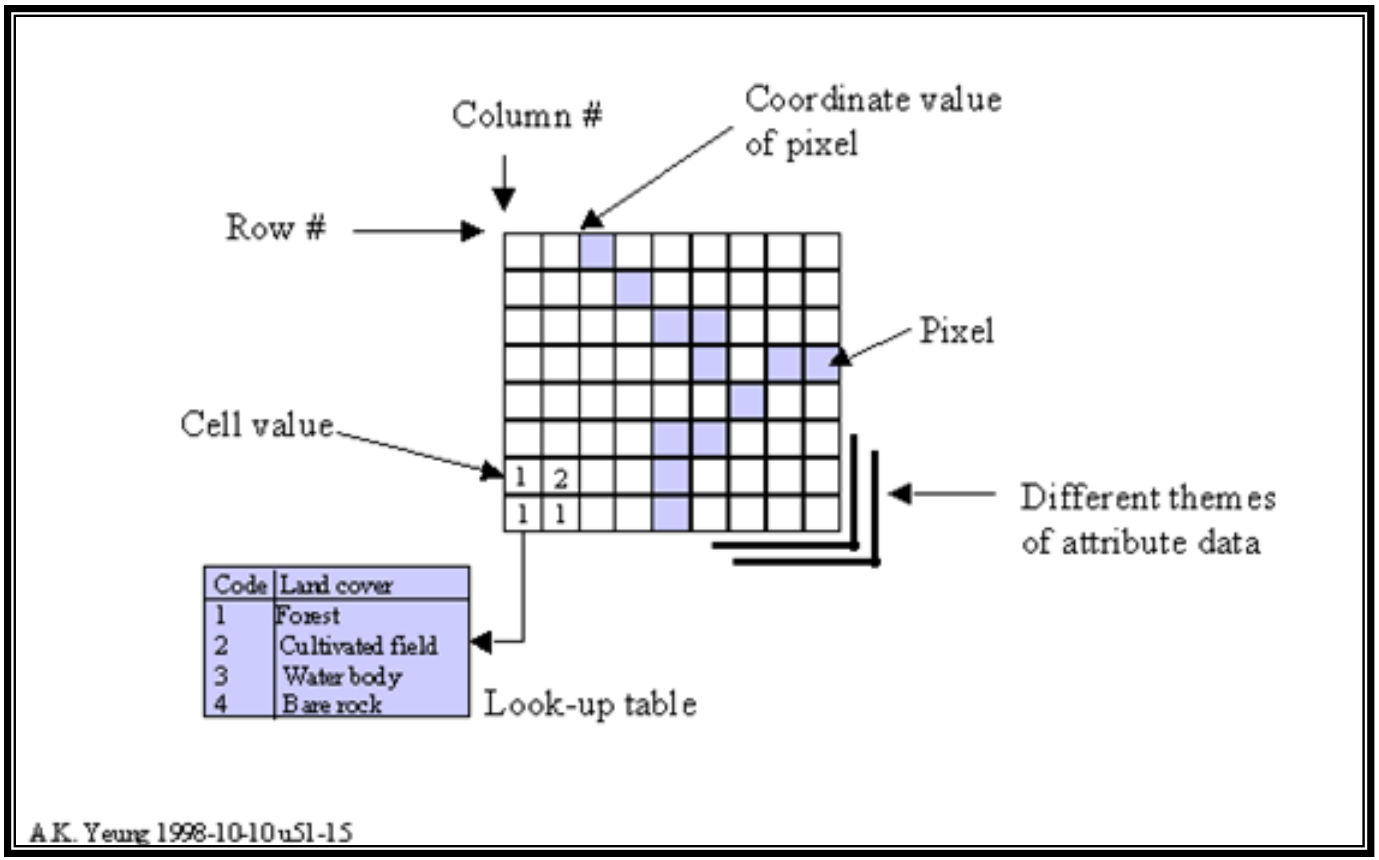
Cells - Coded Values

•Here, the values stored in each cell are used as **substitutes** for some **nominal** or **categorical** data, e.g. land cover classes:

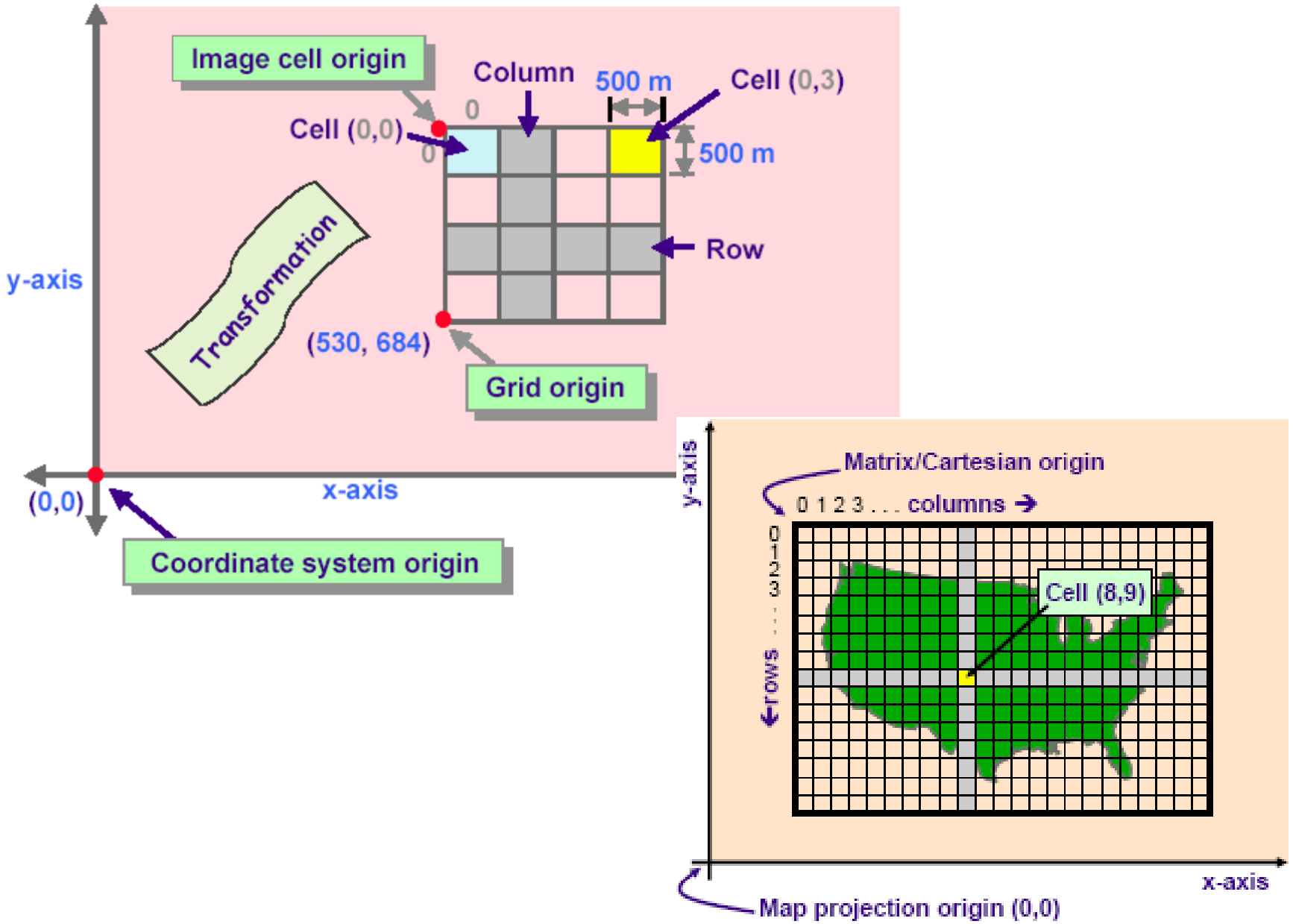
ID	Land Cover Type	Ownership
1	Grass	Smith
…		
8	Water	Smith
13	Sand	Smith

Cells – Coded Values

•The coded values can then **link** to one (or more) attribute tables that associate the cell values with various themes or attributes:

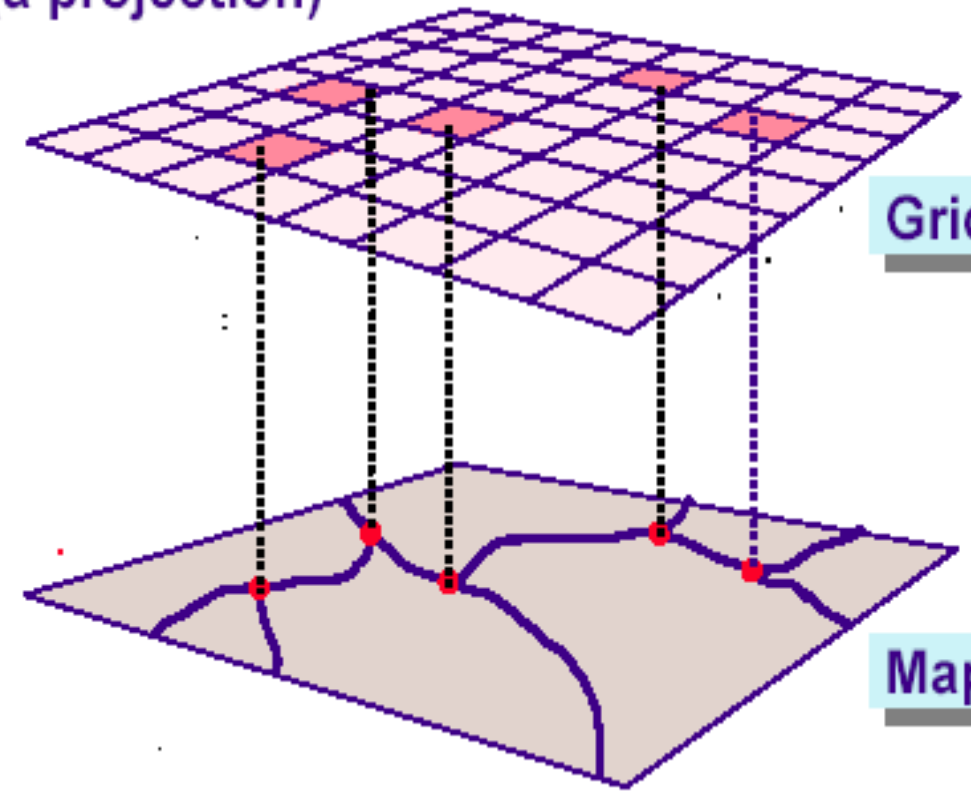


Raster coordinate systems



Raster registration and georeferencing

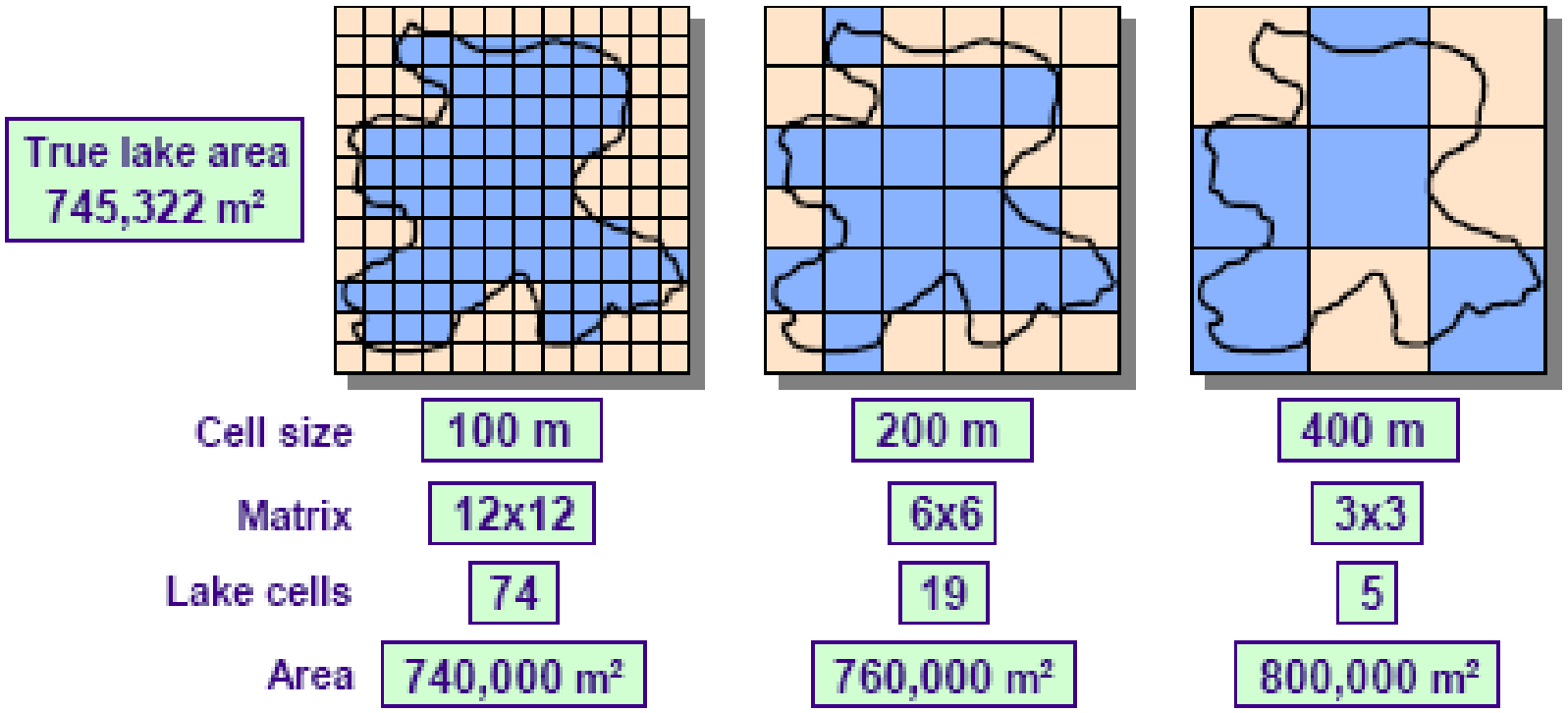
- Raster data should be registered to real-world coordinates (a projection)



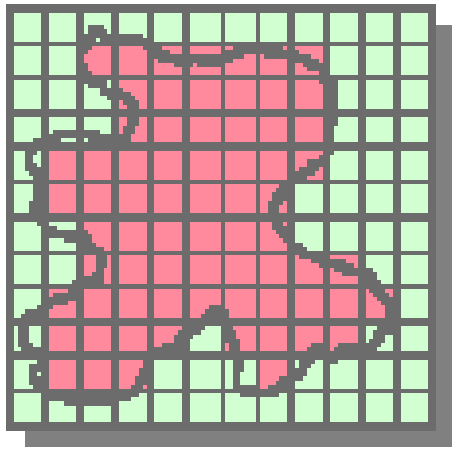
- If all rasters are registered to a common projection, they are registered to one another

Raster Resolution

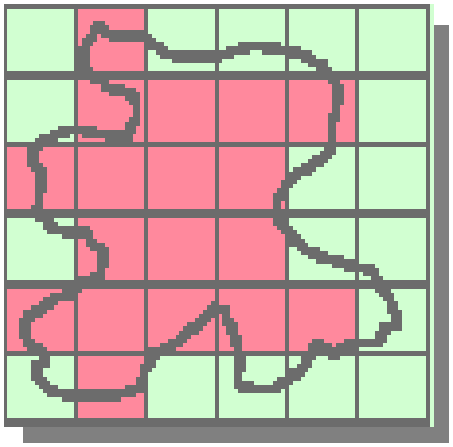
- **Cell size**: smaller cells → higher resolution
  - Impacts accuracy, processing speed, storage



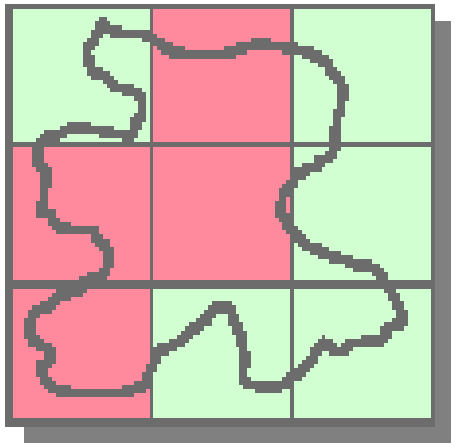
Raster generalization



700,000 sq. meter
100 m cell
12 x 12 grid



720,000 sq. meter
200 m cell
6 x 6 grid



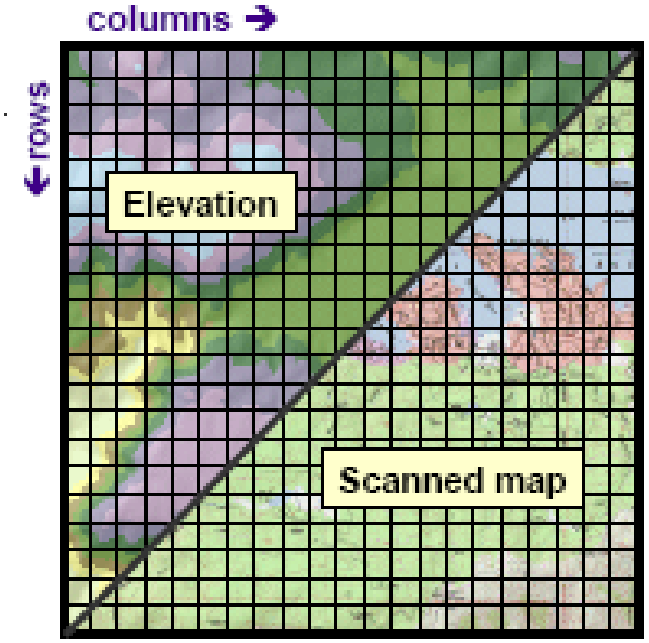
640,000 sq. meter
400 m cell
3 x 3 grid

True polygon area = 679,707 sq. meter
Larger cells = lower resolution

- Accuracy
- Implications
  - Storage space
  - Processing speed

Raster Format Essentials

- All raster formats are **basically the same**:
  - Cells in a **matrix** of rows and columns
  - Contents: Data or picture?
- **Raster data**
  - Elevation, Landuse, Population
  - Analysis (Slope)
  - Mapping (Thematic, Derivative products)
- **Raster pictures**
  - Scanned maps
  - Satellite images
  - Good for mapping (as backgrounds)
  - Bad for analysis

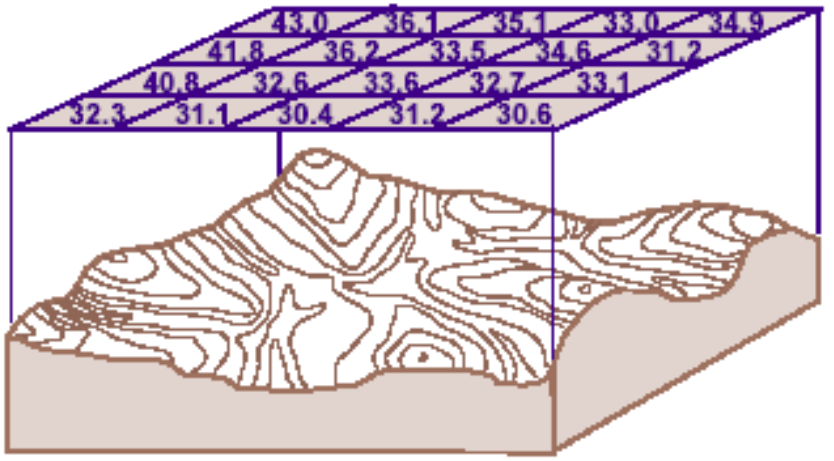


Why Use Raster?

- **Easier** than vector in **many** analyses
- **Fast overlays** with complex data
- More analysis **options**
- Allows:
  - Location view of data
  - Surface analysis (visibility, etc.)
  - Distance analysis (weighted, decay distances, etc.)

Discrete and Continuous Data

- **Discrete data**
  - Models **bounded** data
    - Land use, zoning, and so on
  - Stored as **integer values**
- **Continuous data**
  - Models **surfaces**
    - Elevation, distance
  - Stored as **floating-point or integer values**

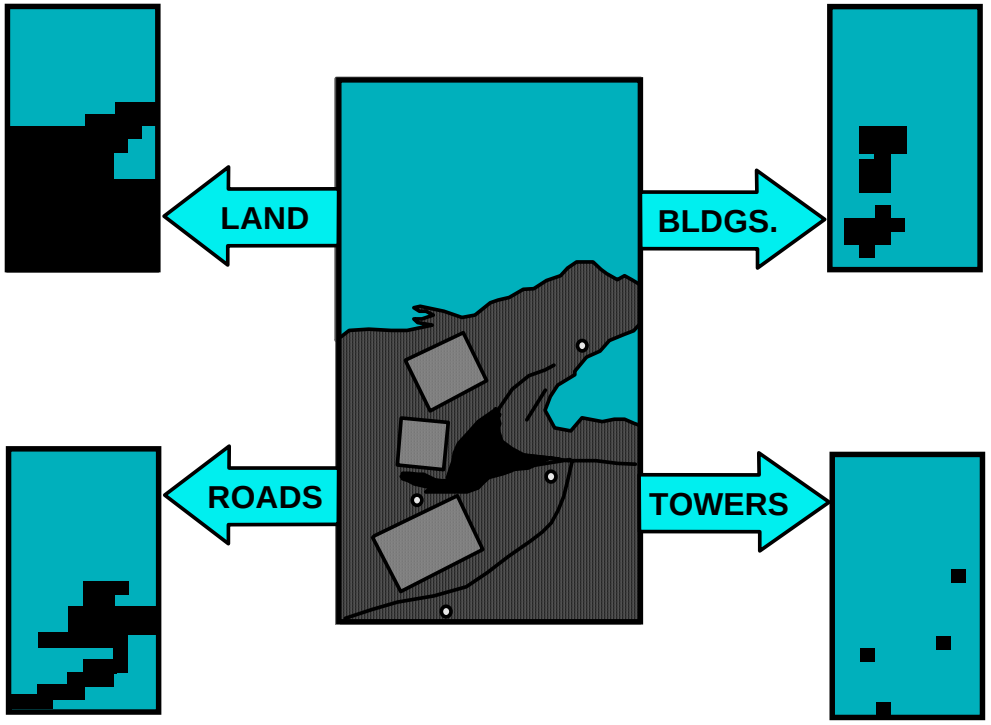


Quantizing Geographic Space

- **Converts both** discrete and continuous data into **discrete packets**
  - **Less exact** locationally than vector
  - Stores all entities in **uniform** fashion
  - As **amount of ground** represented by grid cells **increases** (decreased resolution) the **locational accuracy decreases**

Entities to Raster

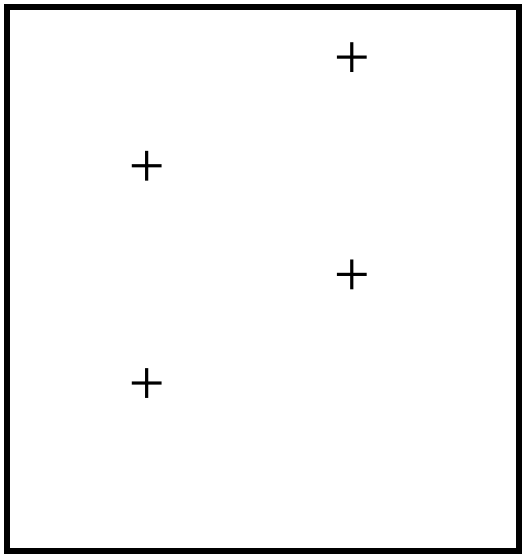
- Once **objects** (entities) are **selected**:
- **Divide** into **quanta**
  - i.e. packets of information
  - Requires **deciding**…
    - Minimum mapping unit
    - Grid cell size
    - Tessellation type

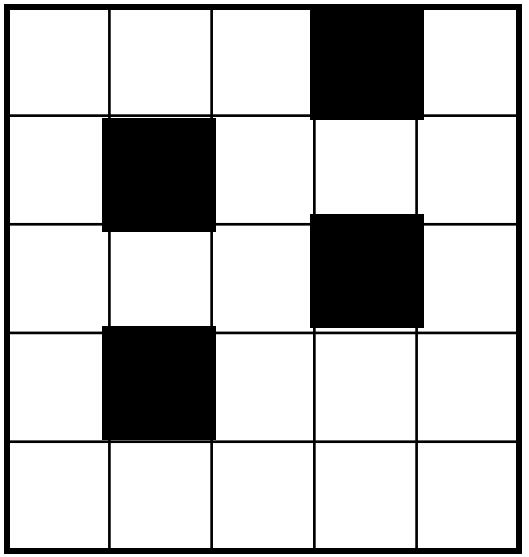


Grid Cells

- **Represent** known or perceived **entities**
  - Plus their **descriptive information** (attributes)
- Typical **entities**:
  - **Points** (single grid cell)
  - **Lines** (strings of grid cells)
  - **Polygons** (areas or groups of grid cells)

Raster Data Model - Points

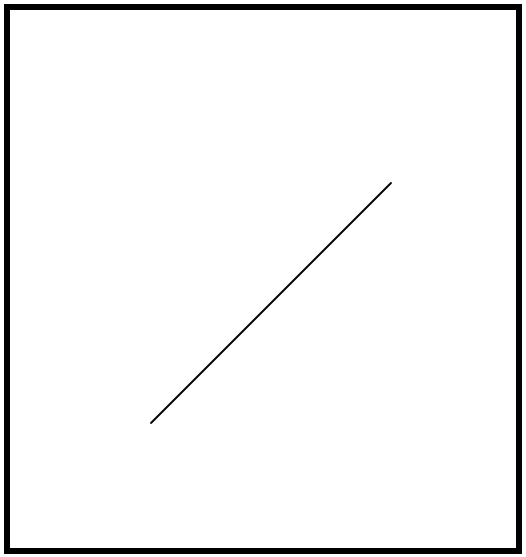


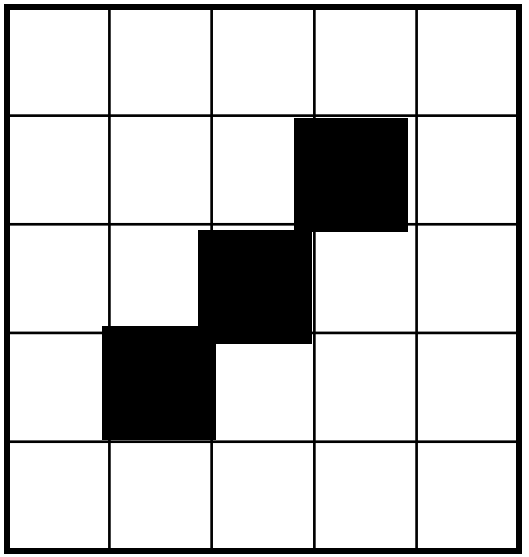


1 point = 1 cell

What problem do we have here? How can we solve it?

Raster Data Model - Lines

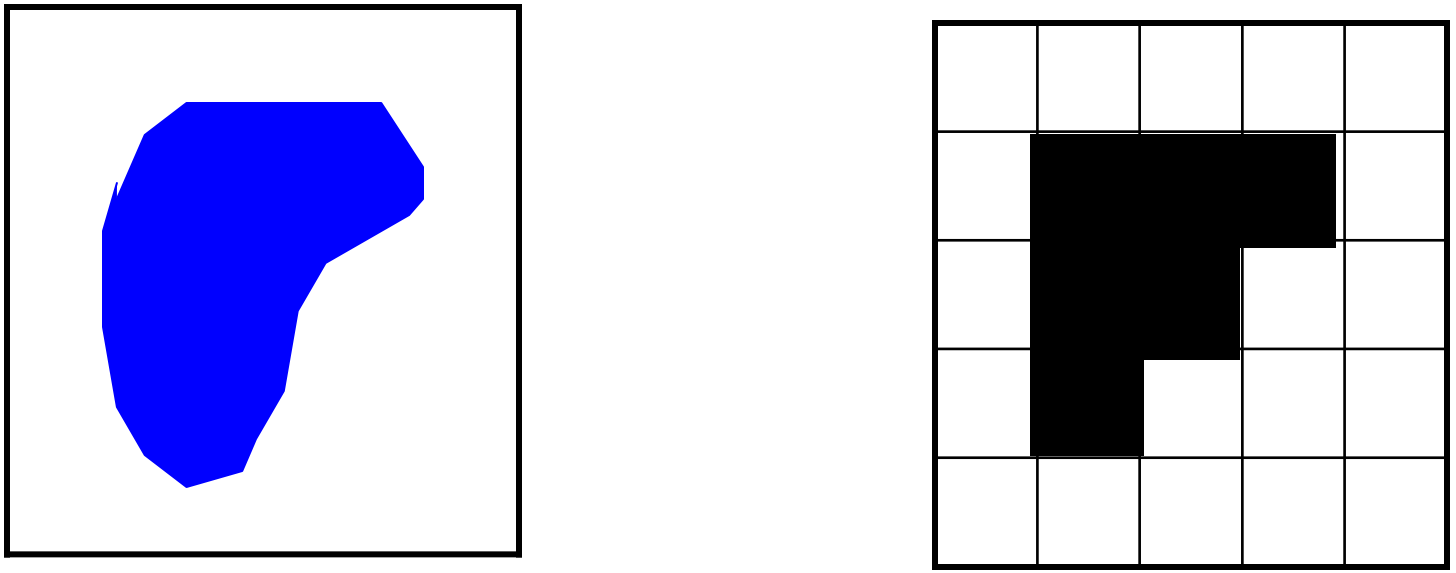




A line = a series of connected cells that portray length

Is there a problem with this representation?

Raster Data Model - Polygons

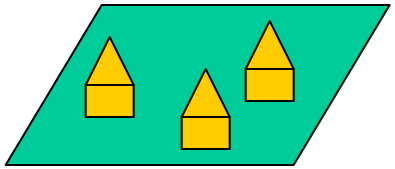


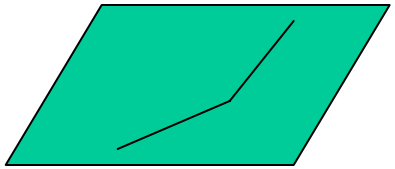
Area = a group of connected cells that portray a shape

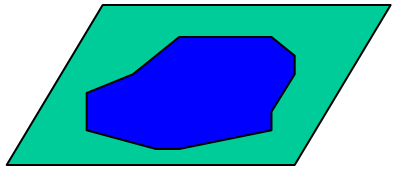
What problems could we have with this representation?

Raster and Vector Data Model Comparison

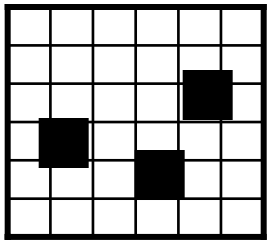
Real World Features

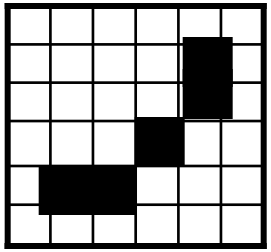


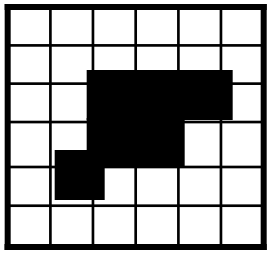




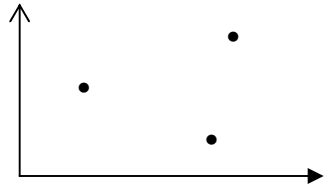
Raster

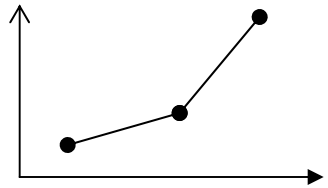


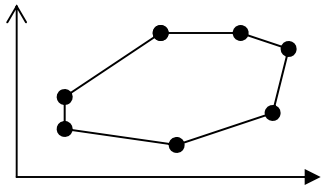




Vector

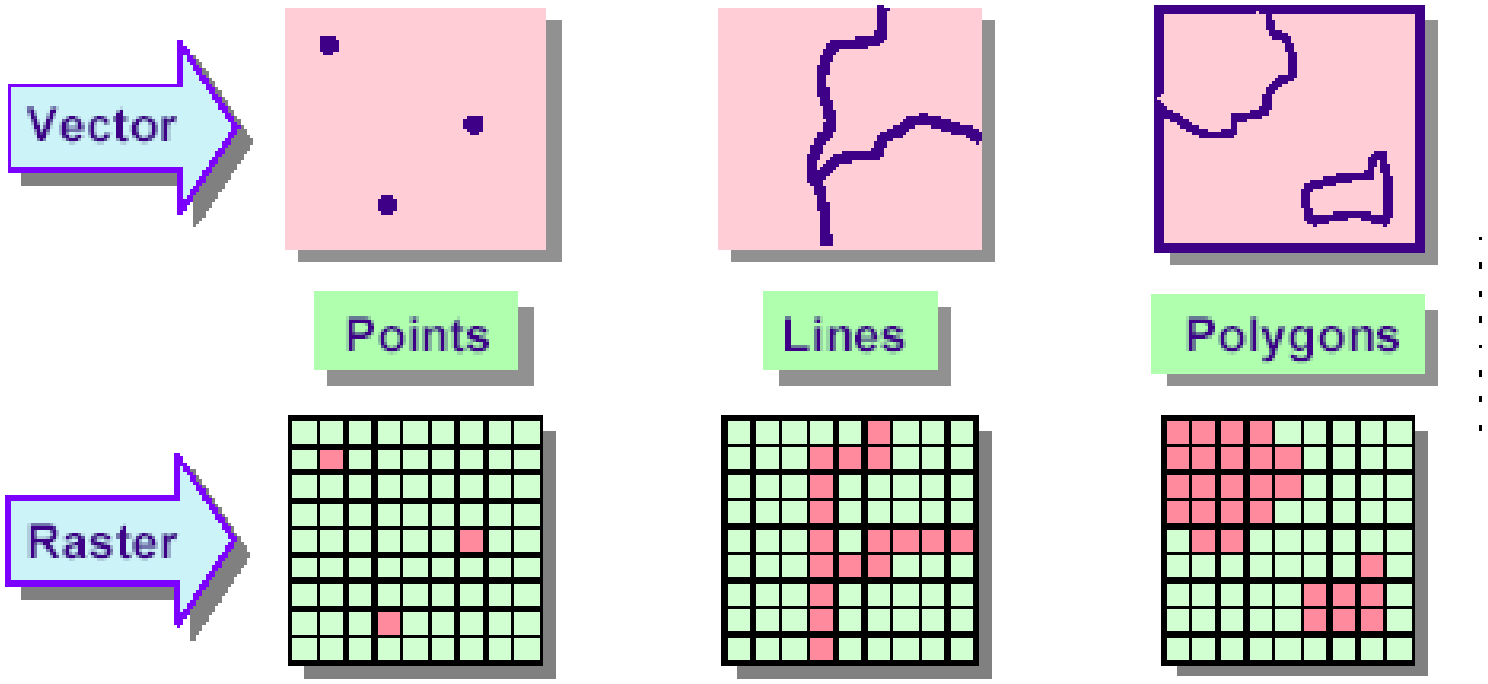






"A raster model tells what occurs everywhere, while a vector model tells where every thing occurs"

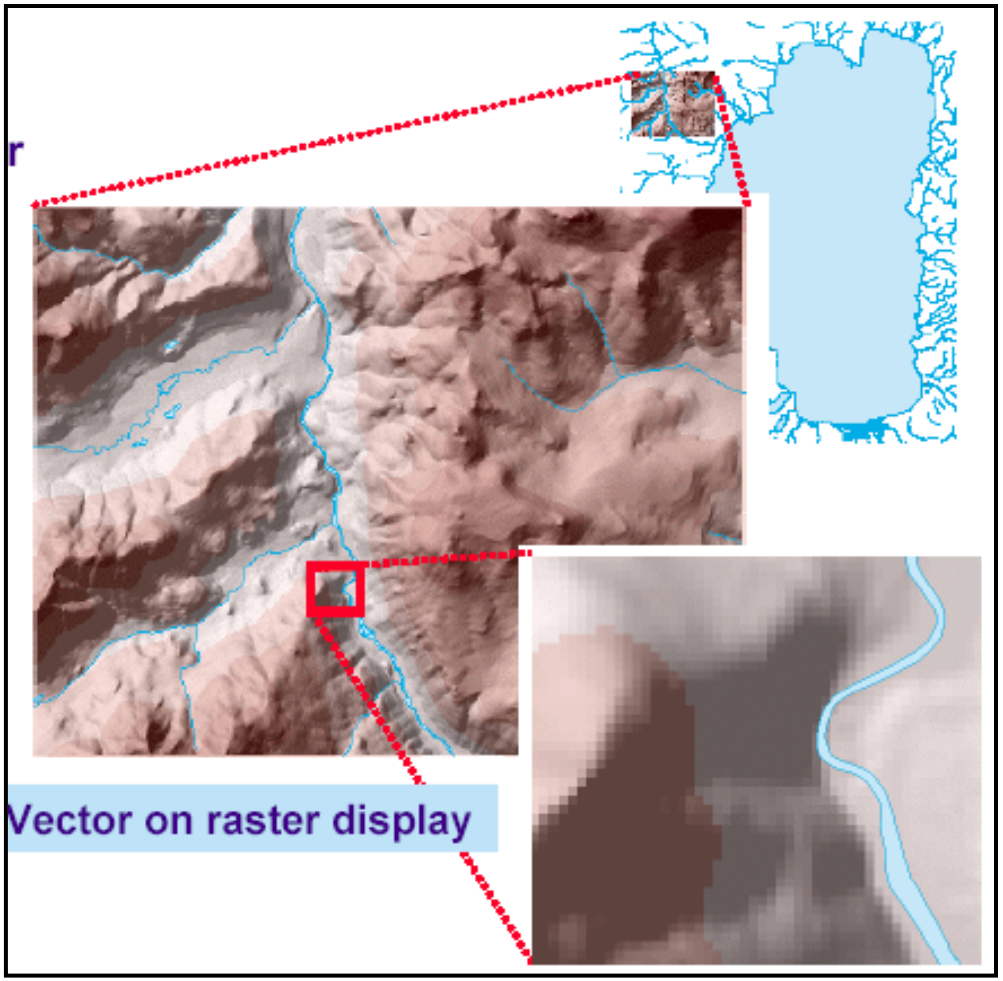
Features as raster



- Raster loses feature uniqueness
  (a line is a collection of cells, not one feature)

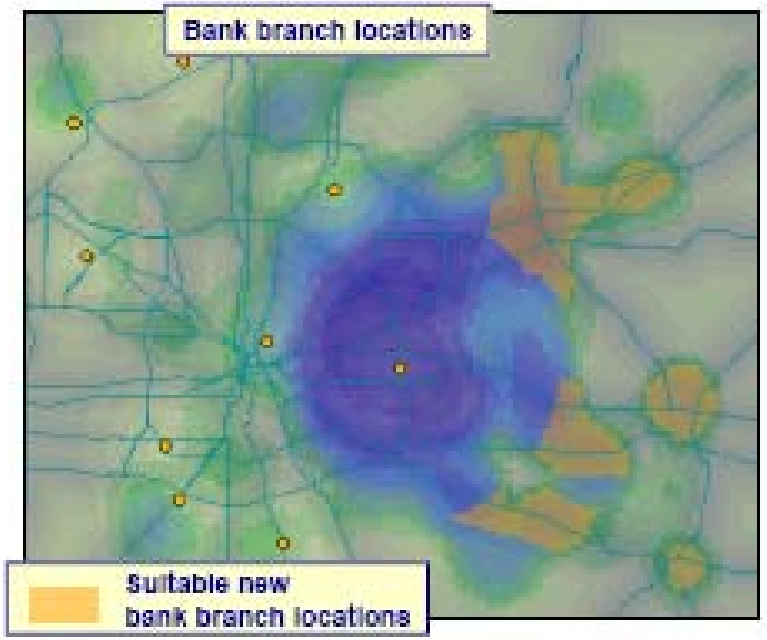
ArcMap Raster Tools

- **Display** in ArcMap
  - **Both** raster and vector
  - Order of display
  - Transparency
- Raster data **can be**:
  - ArcSDE rasters
  - GRIDs
  - Images



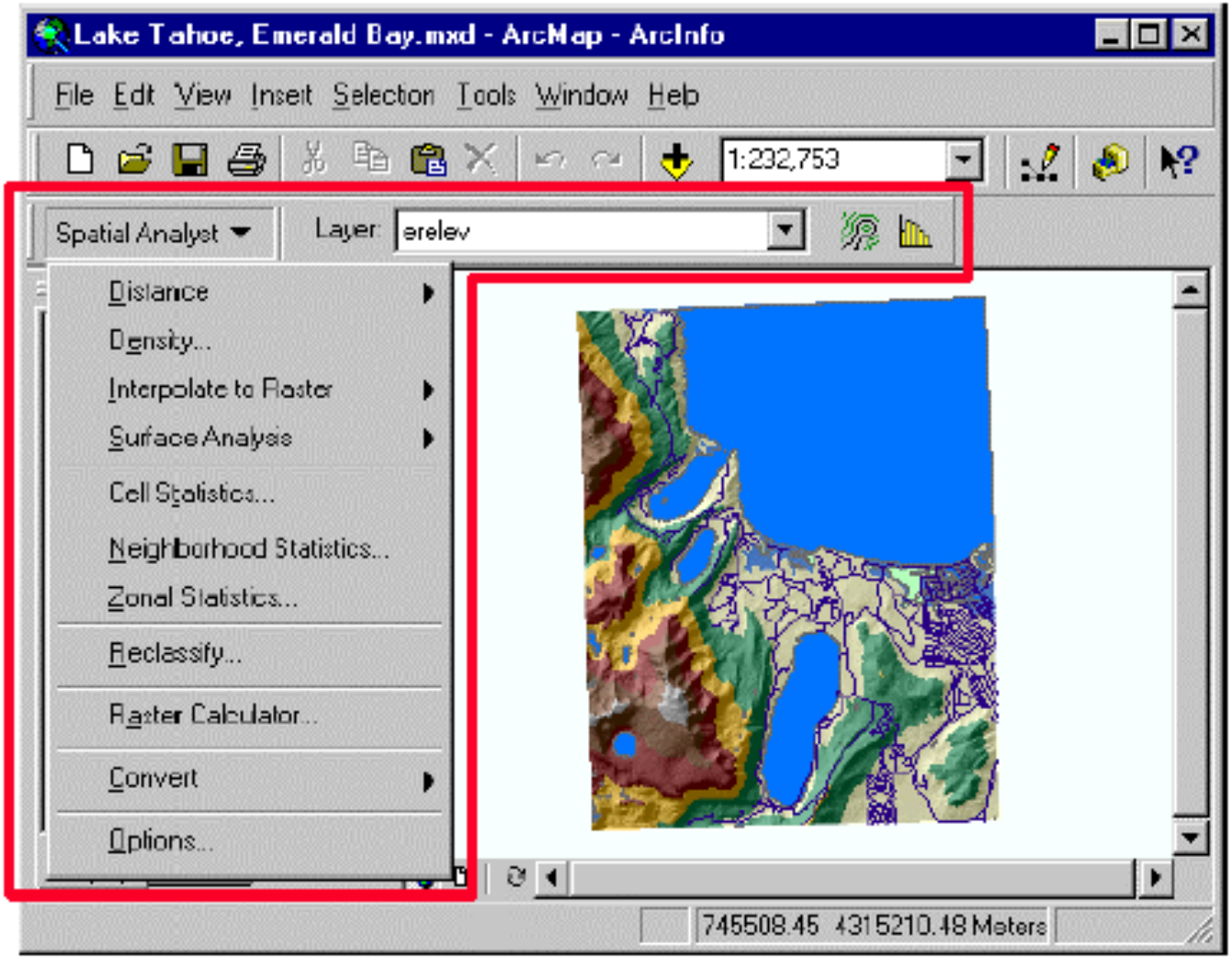
ArcGIS Spatial Analyst

- Provides a rich **modeling environment**
  - –Derive **new information**
  - –Identify **spatial relationships**
  - –Find **suitable** locations
  - –Calculate (travel) **cost**
  - –Can be used with all **cell-based** GIS data

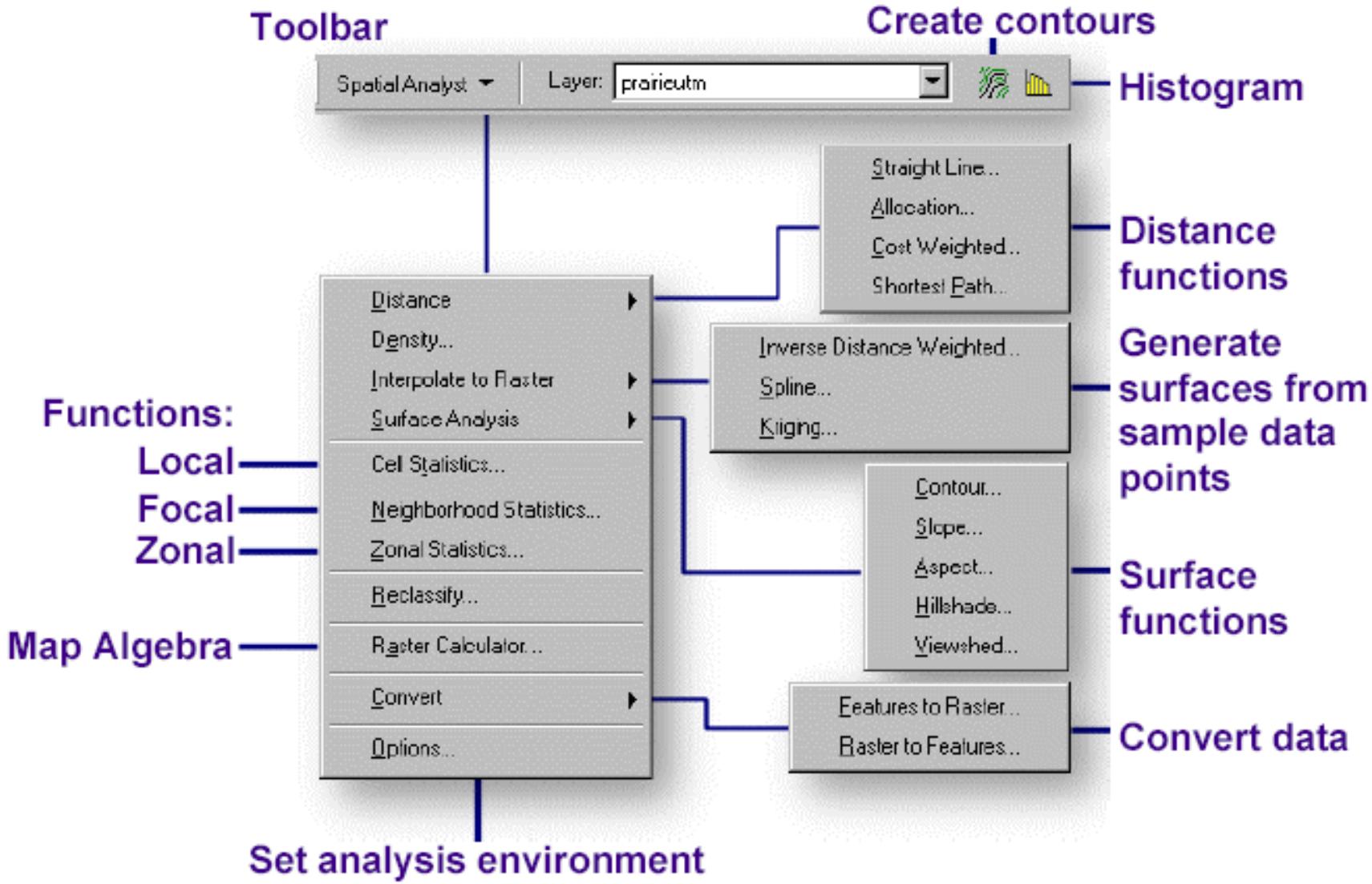


ArcGIS Spatial Analyst in ArcMap

- Toolbar in ArcMap

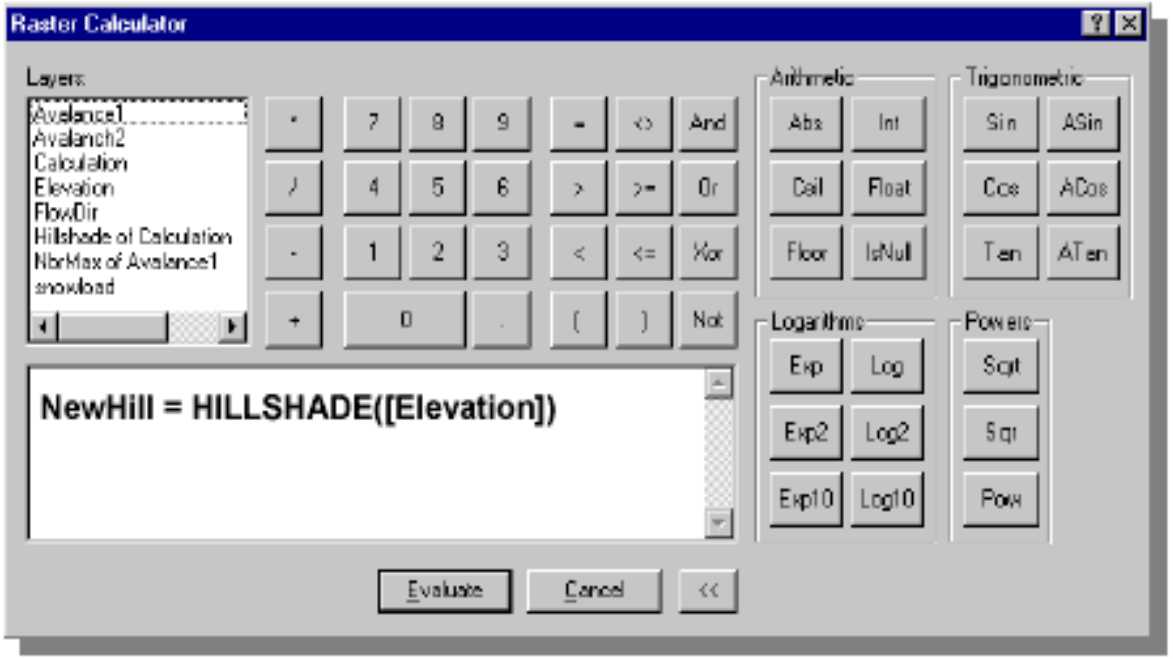


The ArcGIS Spatial Analyst user interface



Map Algebra and the Raster Calculator

- Map Algebra
  - Build expressions
  - Operators
  - Functions
  - Rules and syntax

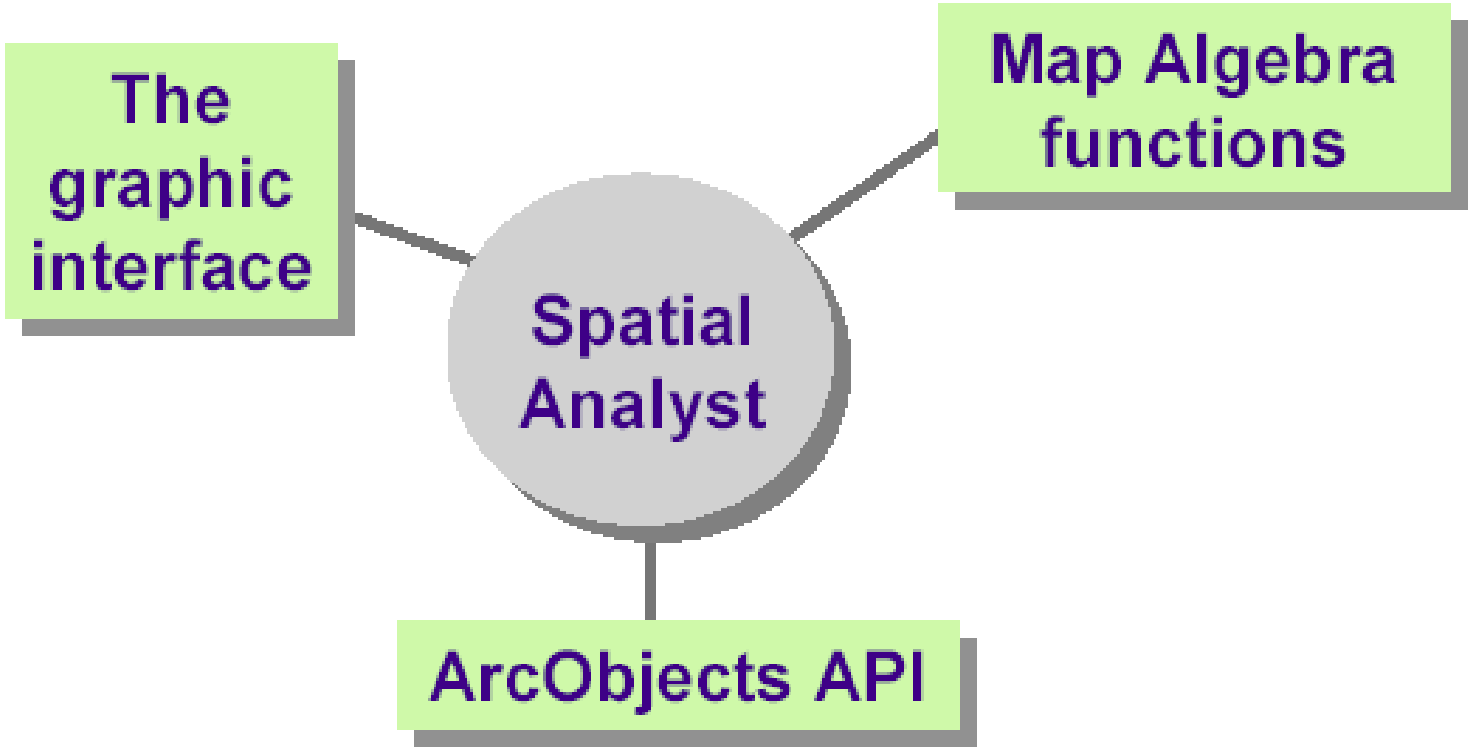


- Use the Raster Calculator to enter expressions
  - For features not on the user interface or advanced analysis

	Total	In UI	In RC only
Operators	29	15	14
Functions	168	51	117
Totals	197	66	131

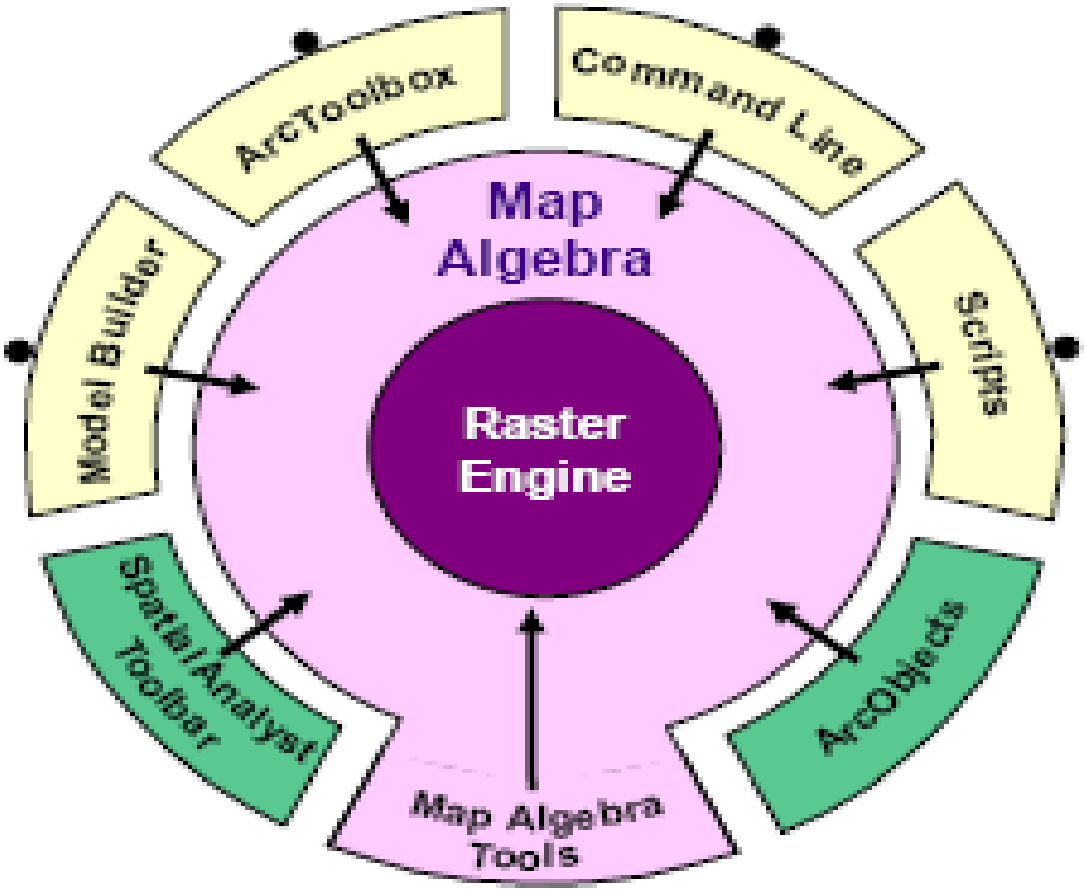
ArcGIS Spatial Analyst is flexible

- Activate the extension
- Add the toolbar



- Analyze all supported rasters

Seven Interfaces for Spatial Analyst



- Part of the geoprocessing framework (share a common environment)

Cell value storage

- Long Integer
  - Range of legal values
- Single precision floating point
  - Range of legal values
- NoData
  - What it is
  - What its value is

Integer

2	1	1	1
No Data	1	1	1
No Data	1	2	2
1	1	2	2

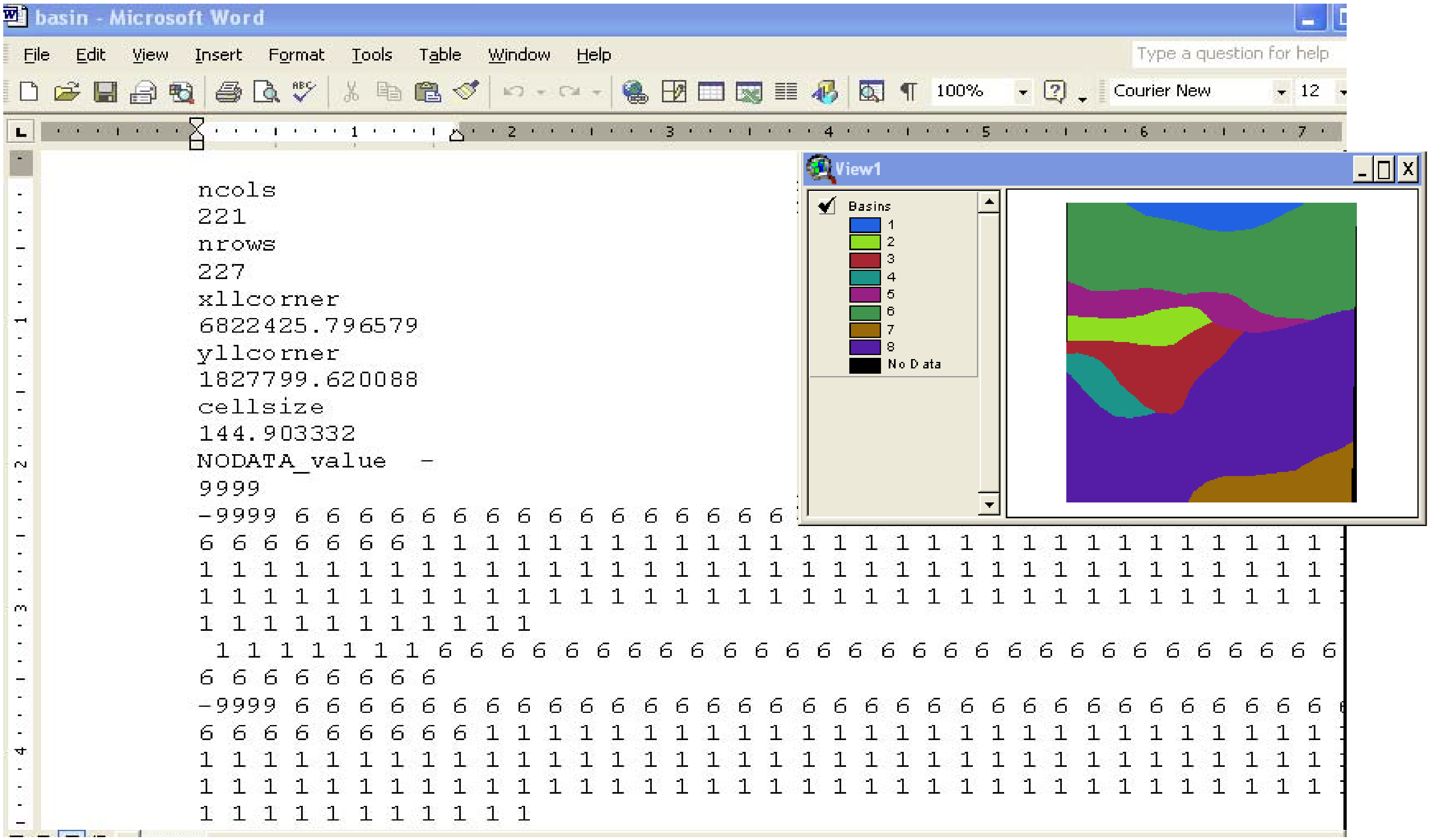
1 Forest
2 Water

Floating point

1.112	3.822	3.755	3.432
0.257	1.829	2.867	2.993
0.000	0.923	0.712	0.448
0.000	0.181	No Data	No Data

Rainfall values

Raster Representation in ASCII data format

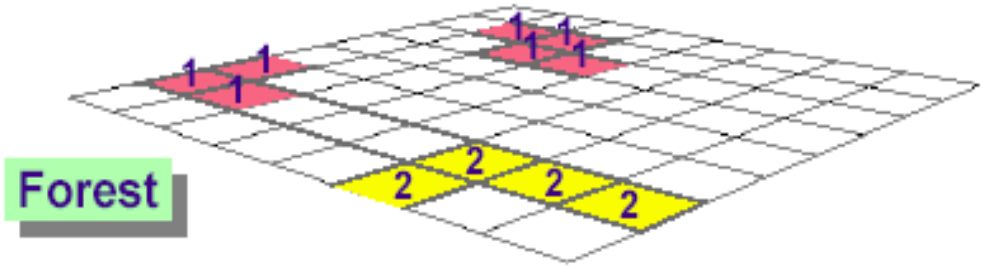


Extending the Raster Model

- An **extension of the raster model** allows it to fit into the **MAP model** (Dana Tomlin's approach, analogous to that in ArcGIS):
  - **Themes** are the primary items being addressed / used / manipulated
  - Extending the raster model allows **rasters to be themes** as well, then by…
    - **Adding / linking tabular data** to the spatial representation
    - Allowing **multiple attributes** for each theme in the raster domain

Grid attributes

- Integer grids may have an attribute table
  - One record per zone (unique values)
  - Always have *VALUE*, *COUNT* fields



Forest

VALUE	COUNT	TYPE	CODE
1	7	MAPLE	400
2	4	OAK	500

User-defined

Relate

Tree_data

VALUE	DENSITY	BUG_DAMAGE
1	65	10
2	74	14

  - You may add fields
  - Relate to other tables with ArcMap
- Floating-point grids
  - No attribute table

Extending the Raster Model, Cont.

- What are the **advantages** over simple raster?
  - Increased **attribute data** for each theme
    - Less storage space
    - More possibilities
  - Puts this **additional data** at users' fingertips
    - As modeling is performed, these **attributes are carried** with each theme
    - Also carried with **newly created themes**

User attributes in expressions

- You may use numeric VAT fields in expressions
- Reference with [Layer].*field* notation

Vegetation.VAT

Value	Count	Desc	Suit
101	2450	Grass	1
201	65780	Mixed	3
301	32187	Pine	2
401	5433	Oak	5

Soil.VAT

Value	Count	Desc	Suit
23	2450	Sand	2
46	65780	Loam	1
87	32187	Clay	6
99	5433	Rock	9

```
[Vegetation].Suit + [Soil].Suit
```

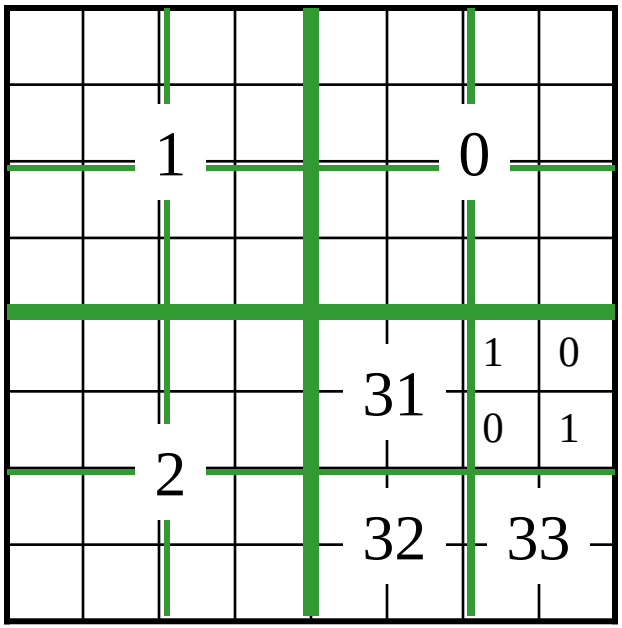
  - [Layer] alone is assumed to be [Layer].Value
- You may join tables to grids VAT file
  - Use joined fields for symbology, selection
  - Cannot use in Map Algebra expressions

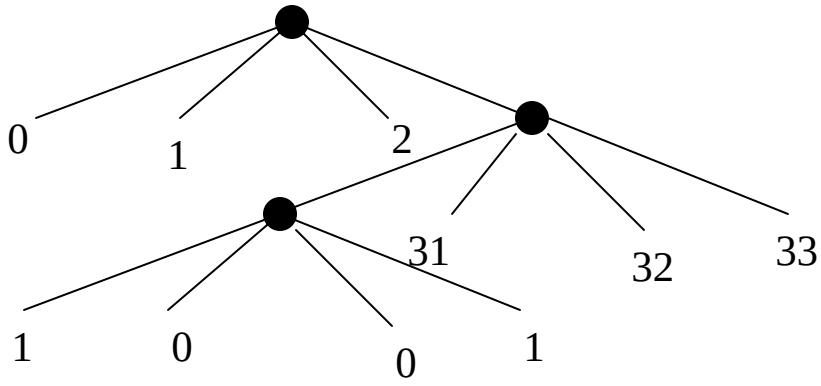
Quadtree Data Model

- So far, all the data models we have seen make use of a **uniform tessellation**
  - Wastes space
- But most **compact tessellations** are not **appropriate** for modeling
- **Quadtrees** (based on AI research)
  - Variable size tessellation
  - Allows modeling

Quadtree Model

The quadtree method **recursively subdivides** the cells of a raster grid into quads (quarters) until **each quad** can be represented by a **unique cell value**:





The number of subdivisions depends on the **complexity** of features and stores **more detail** in areas of greater complexity

Exercise 2: Raster Concepts

- **Explore** raster concepts
- **Set** the raster **analysis environment**
  - Analysis extent, cell size, mask
- **Clip** a raster dataset
  - With the analysis extent (rectangular shape)
  - With the mask (irregular shape)
- **Snap the extent** to a specific raster

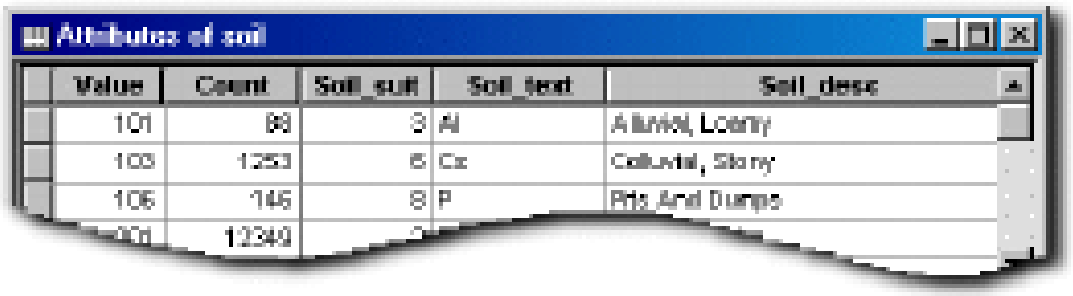
Raster Formats

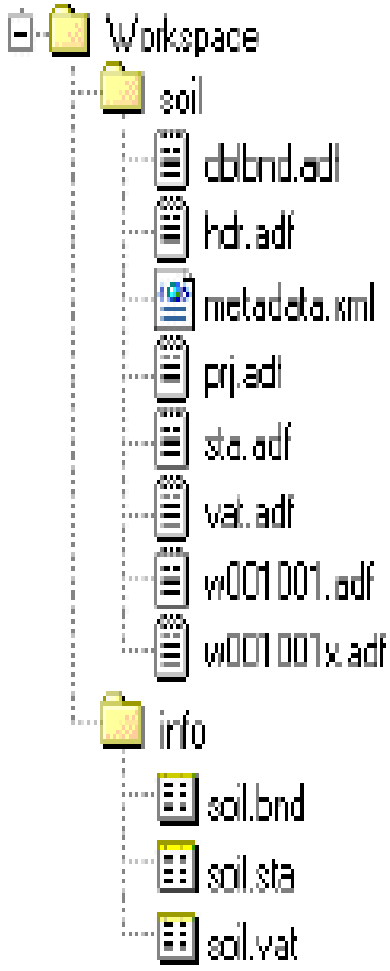
- The data format is **how cells are stored** in a raster
- ArcGIS supports **dozens** of raster formats
  - Various image formats (SID, IMG, TIF, etc.)
  - ESRI GRID Format
  - ESRI ArcSDE raster
  - ESRI raster dataset
  - ESRI raster catalog
  - All may be managed in ArcCatalog
  - All may be used with the Spatial Analyst

ESRI GRID Format

- **Native format** for Spatial Analyst
  - Default output from most tools
  - A folder containing multiple files
  - Have associated INFO tables

    (must manage grids with ArcCatalog **only**)
- **Two types**: Floating point & Integer
- **Integer grids** may have user-defined **attribute fields**

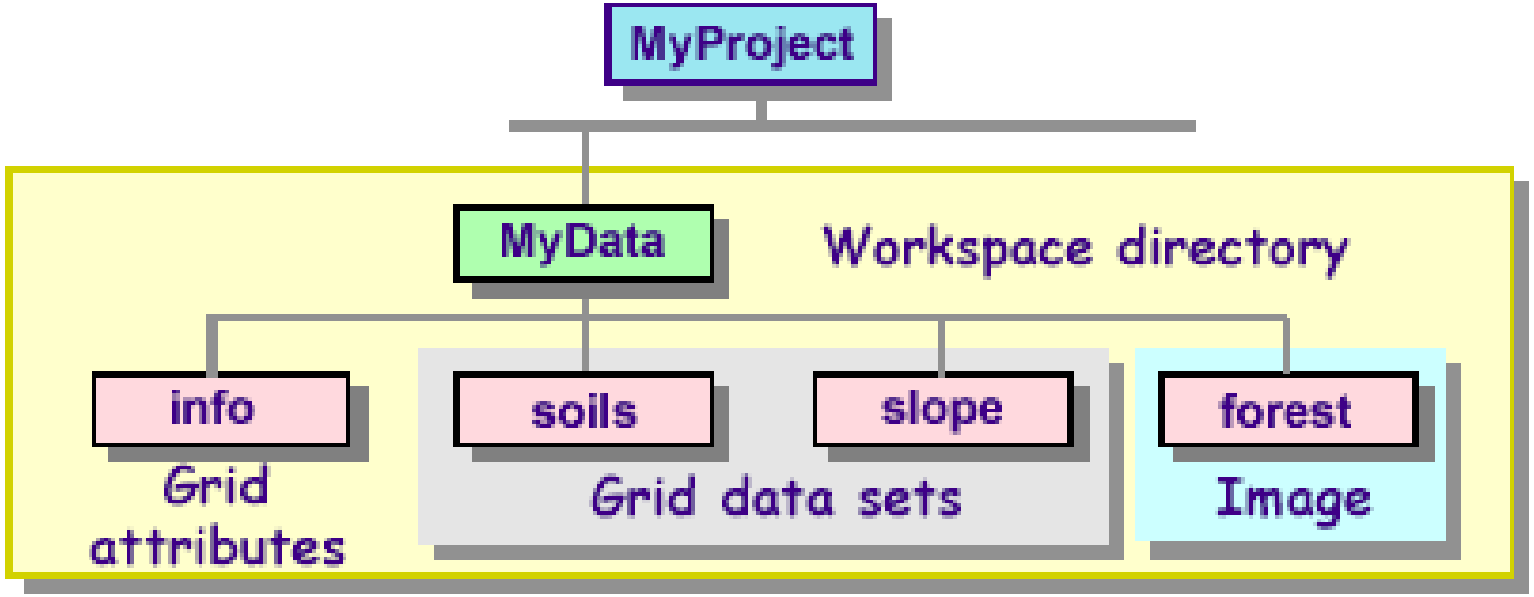




* Stylized representation

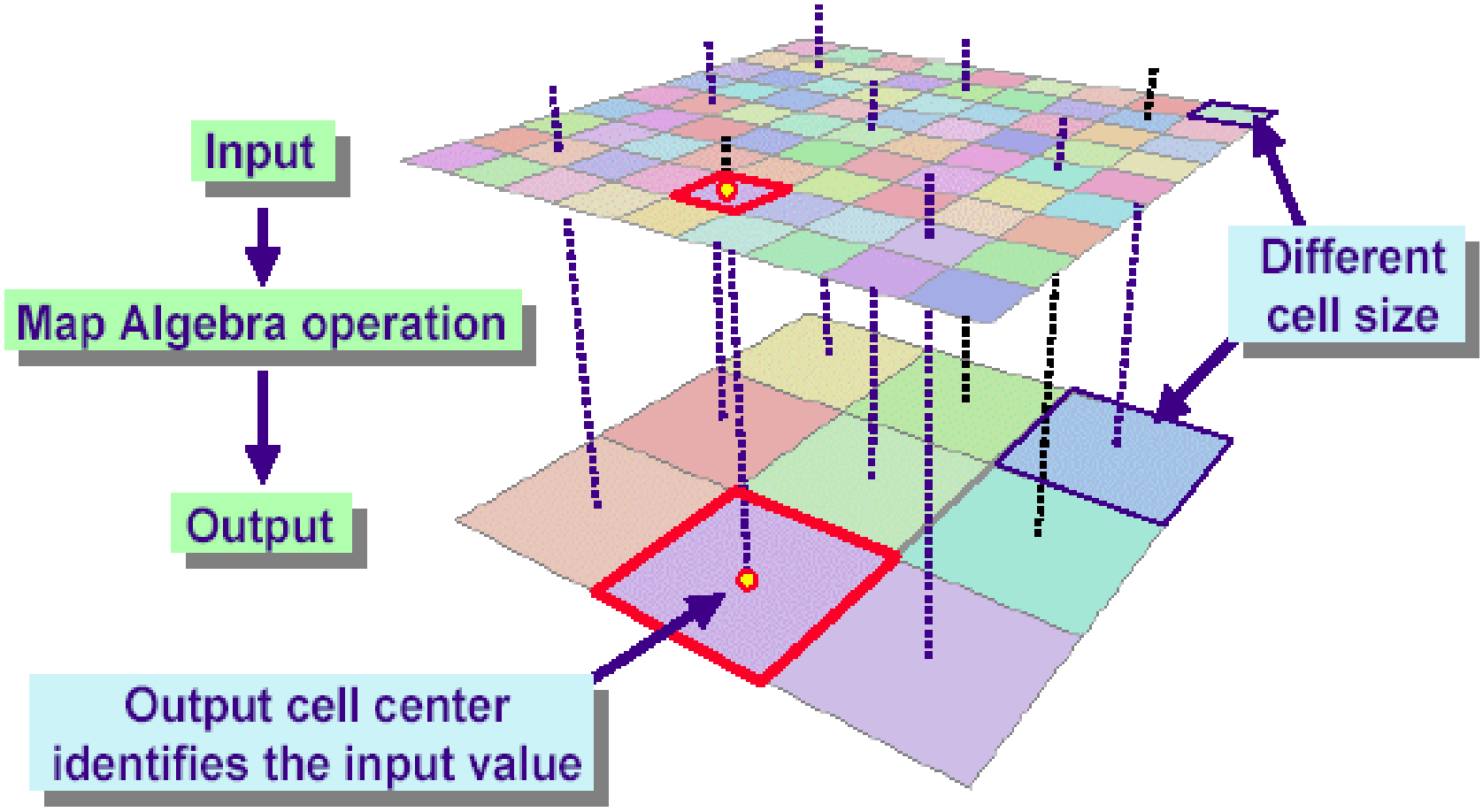
The grid data model

- Native data structure for ArcGIS Spatial Analyst
  - Analysis creates output grids
  - Cells stores data values (not colors like images)
  - May have an attribute table, participate in relationships
- Manage with ArcCatalog

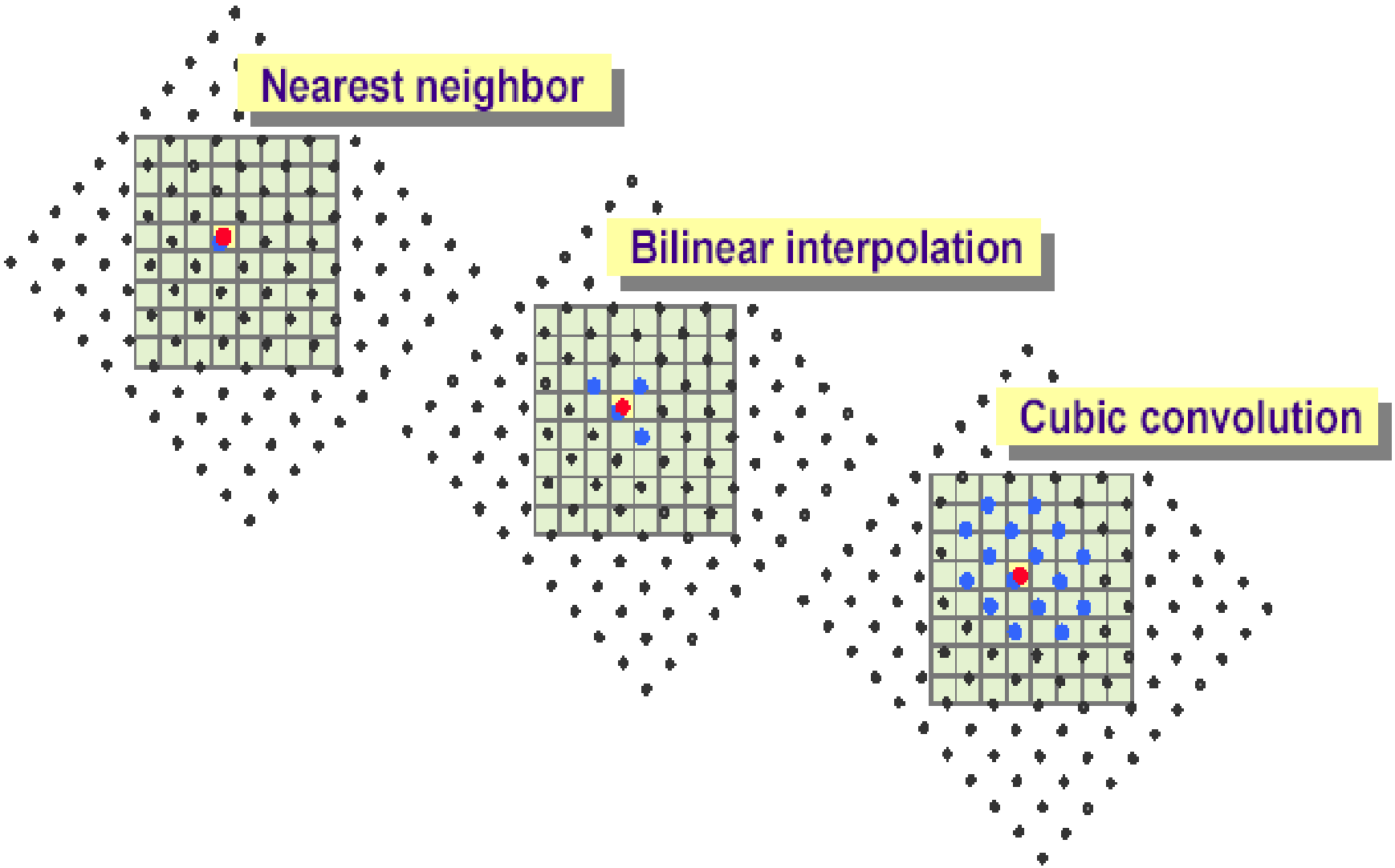


Resampling

- Automatically applied when combining rasters

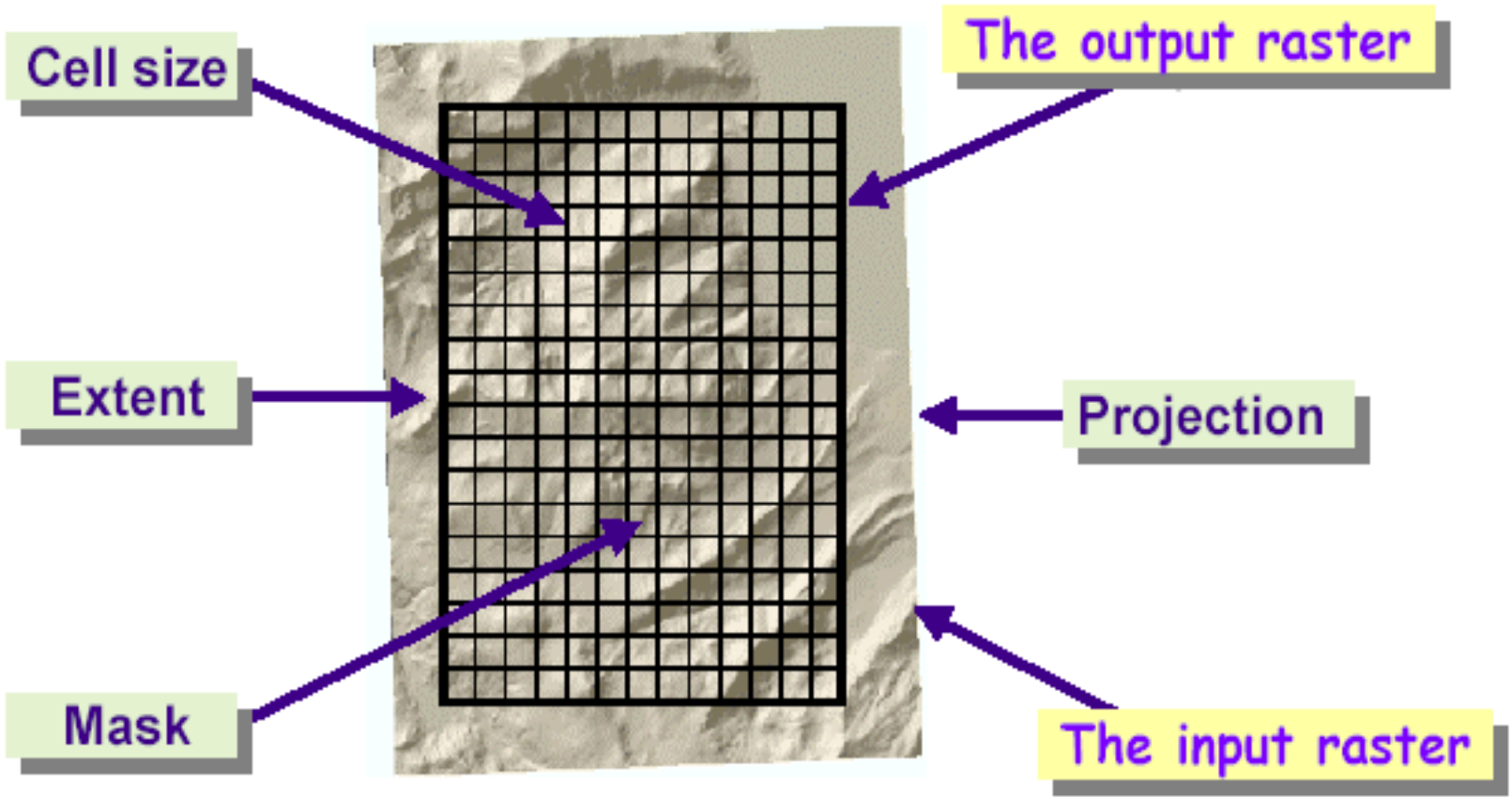


Resampling methods



The analysis environment

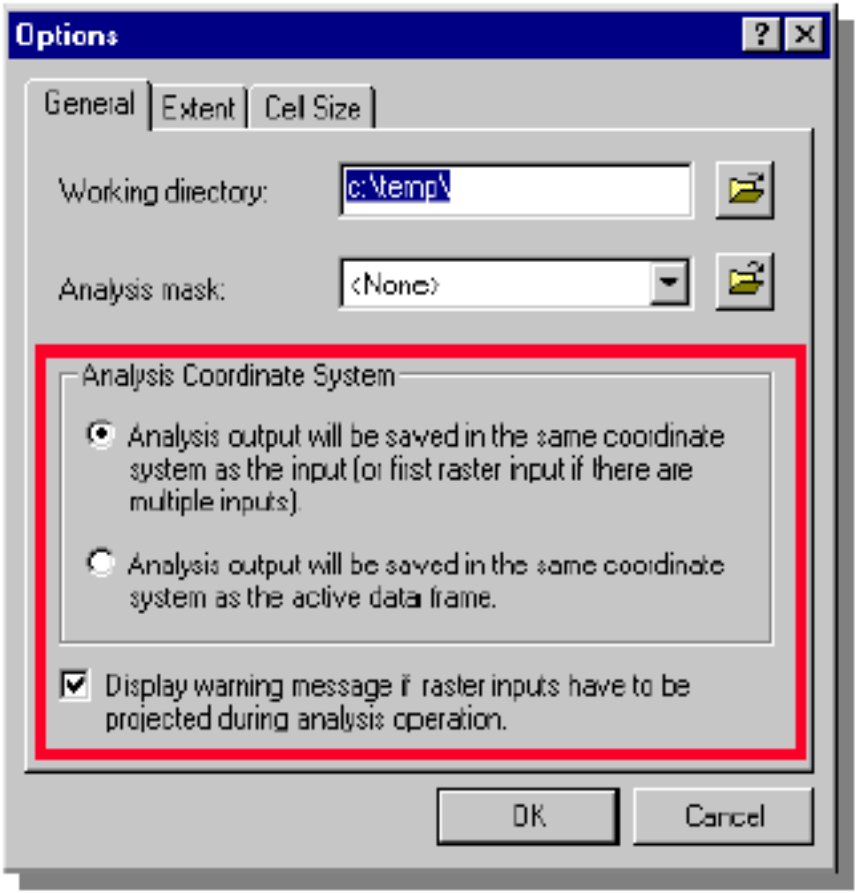
- Controls how the output raster is created



- Set in the ArcGIS Spatial Analyst > Options dialog

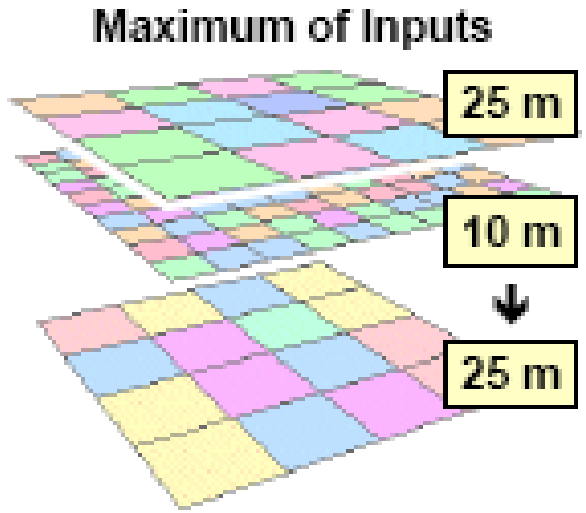
Setting the projection

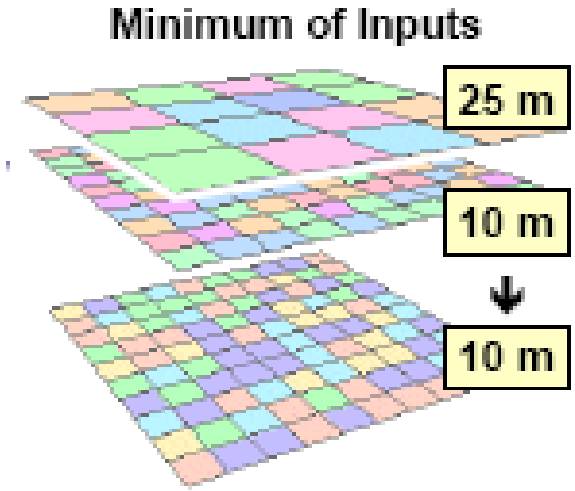
- Rasters may be projected during analysis operations
- Choose an output projection:
  - Same as first input layer
  - Same as data frame
- You may change the data frame projection



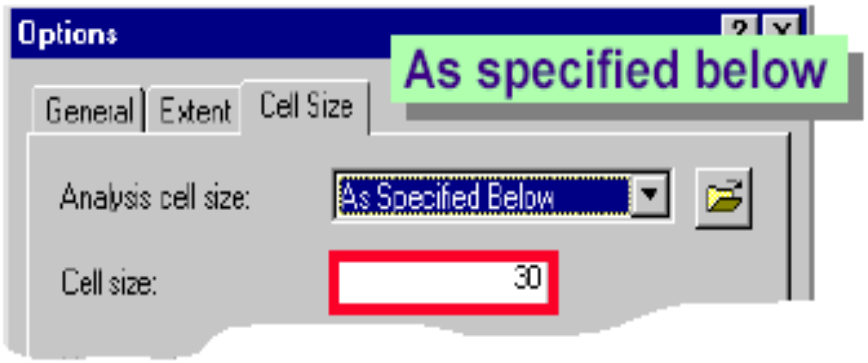
Setting the Output Cell Size

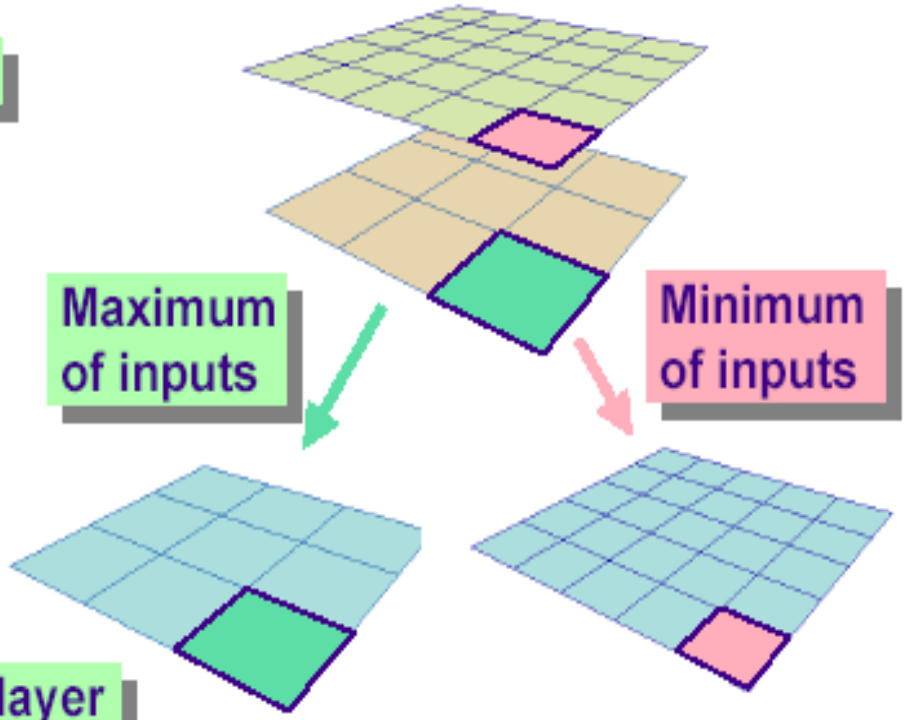
- When **combining rasters** with **different cell sizes**; output another size:
  - Maximum of Inputs (default)
  - Minimum of Inputs
  - Same as Layer
  - As Specified Below

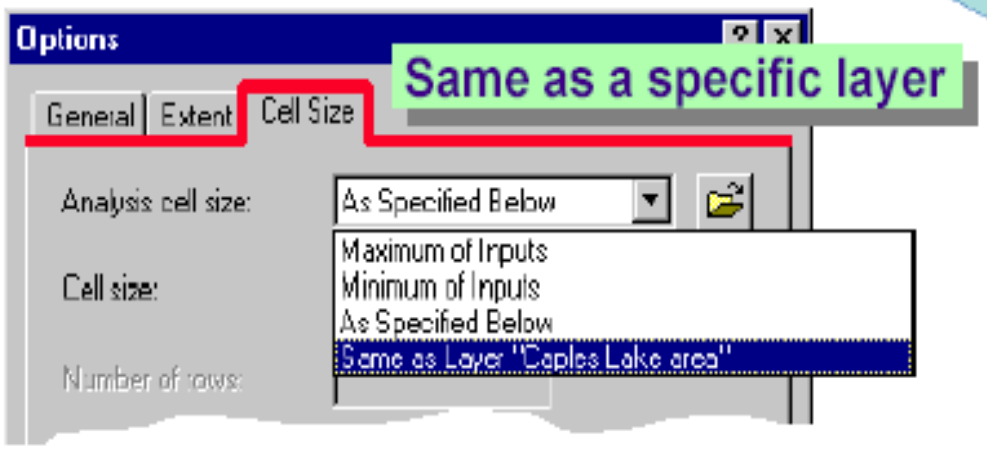




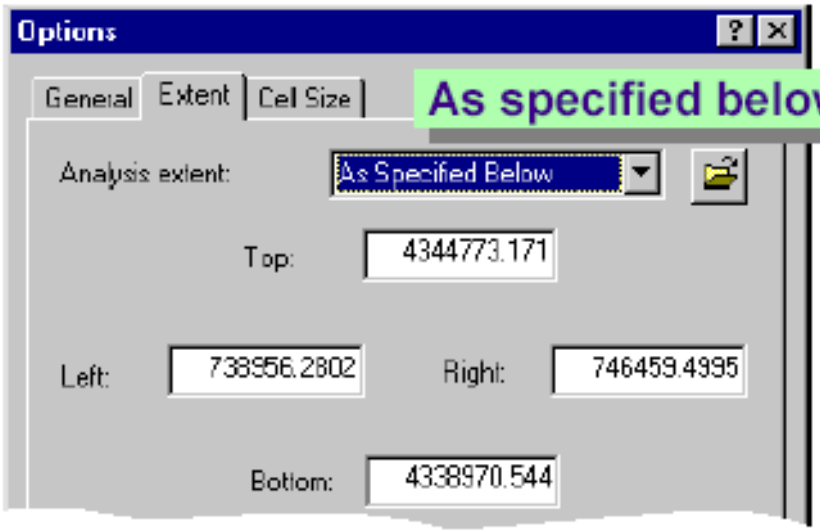
Setting the cell size



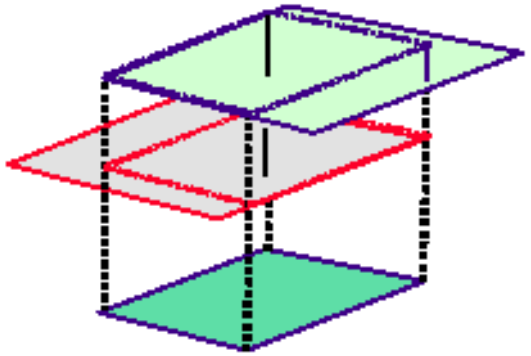




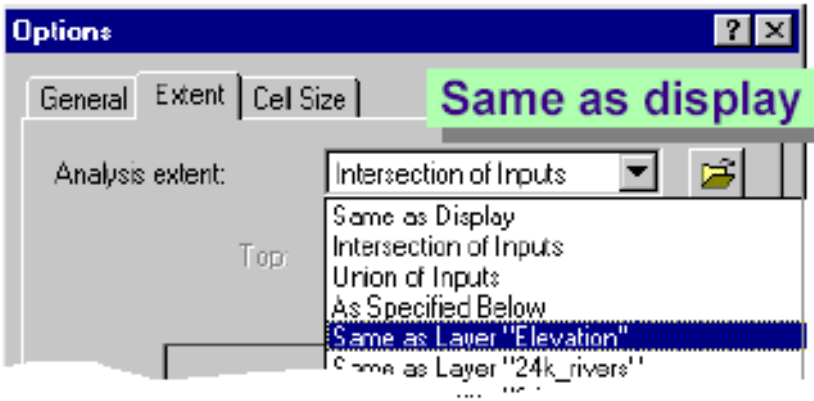
Setting the analysis extent



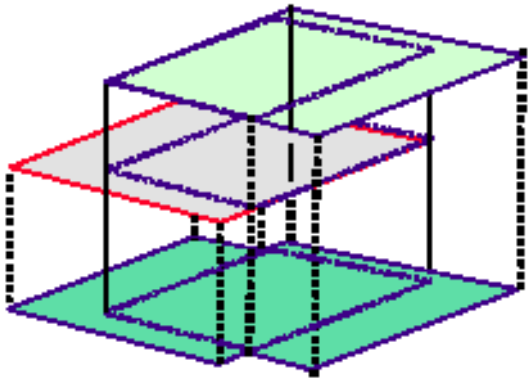
As specified below



Intersection of inputs



Same as display

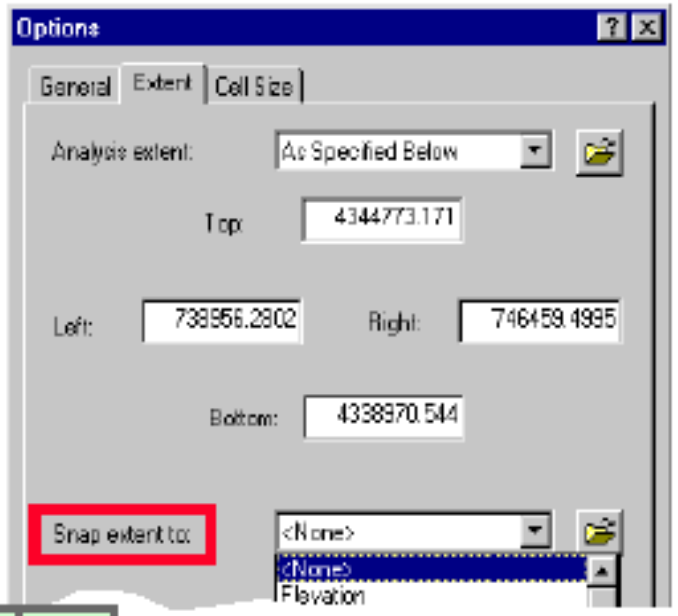


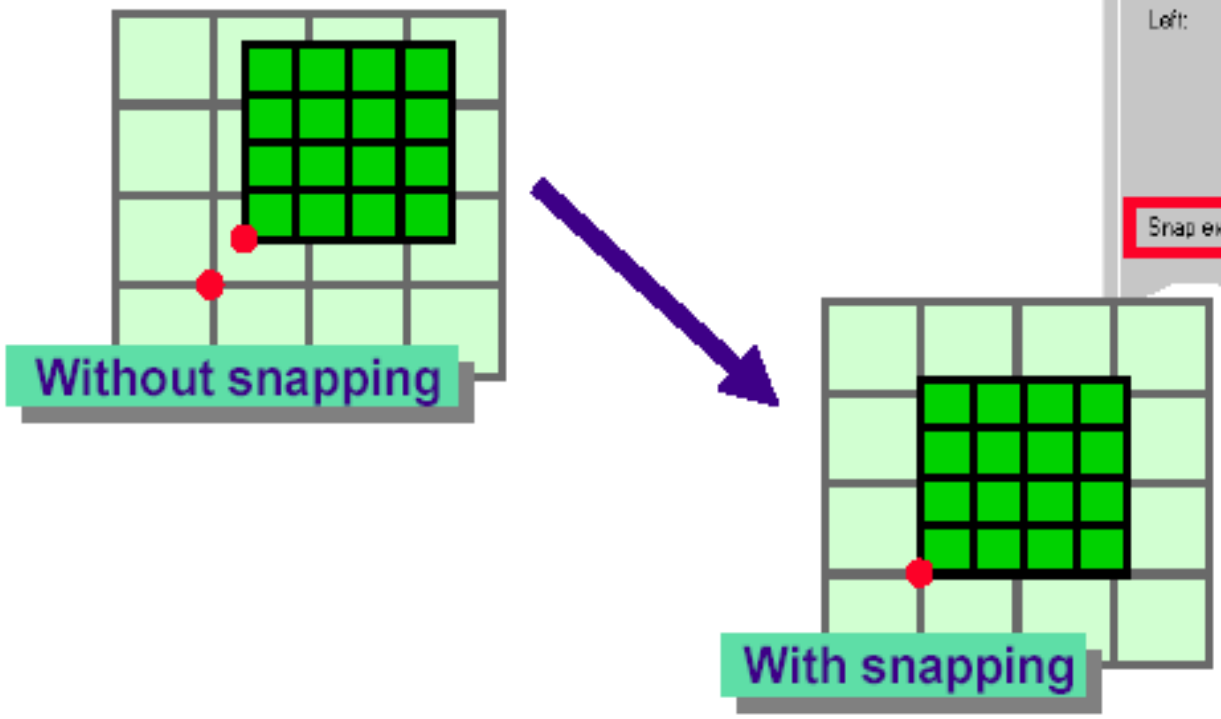
Union of inputs

Same as a specific layer

Snapping the extent

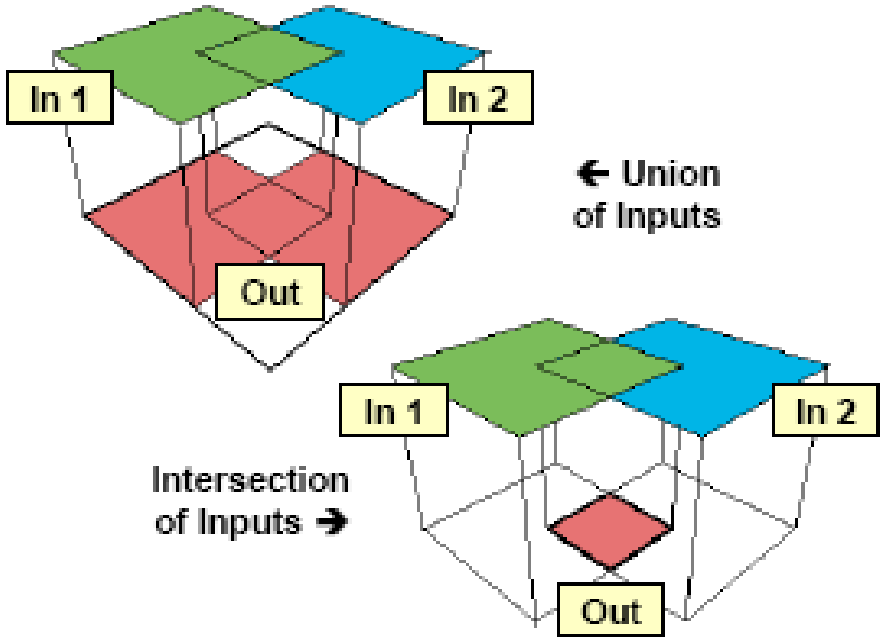
- Snaps the specified extent to cells in a raster layer
  - Ensures that output cells align with the snap layer





Setting the Output Extent

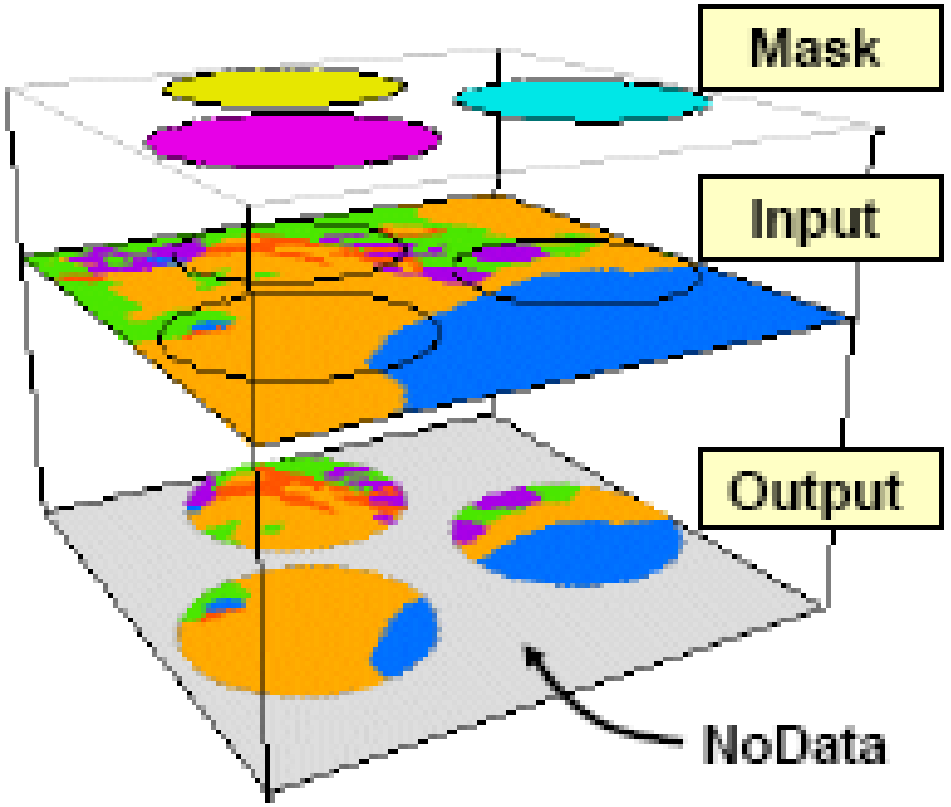
- This **controls the width and height** of the resulting output raster:
  - Combine rasters with **different extents**; output another extent
- Output **options**:
  - Union of Inputs (default)
  - Intersection of Inputs
  - Same as Layer
  - Same As Display
  - As Specified Below



Setting the Analysis Mask

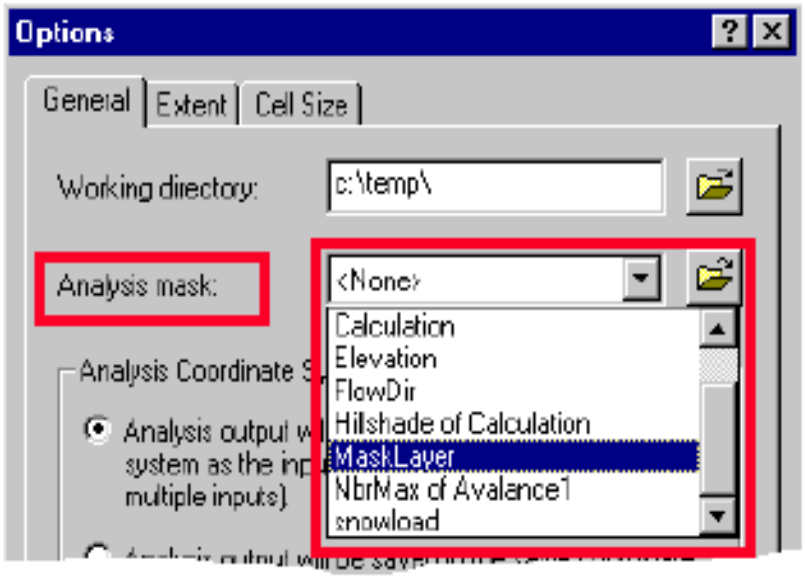
- Vector mask
  - Only **cells covered by features** are output (others set to NoData)
  - Create a feature mask with **selection** and export
- Raster mask
  - Only **cells covered by valued cells** are output (others set to NoData)
  - Create a raster mask with **any number of** Spatial Analyst **techniques**

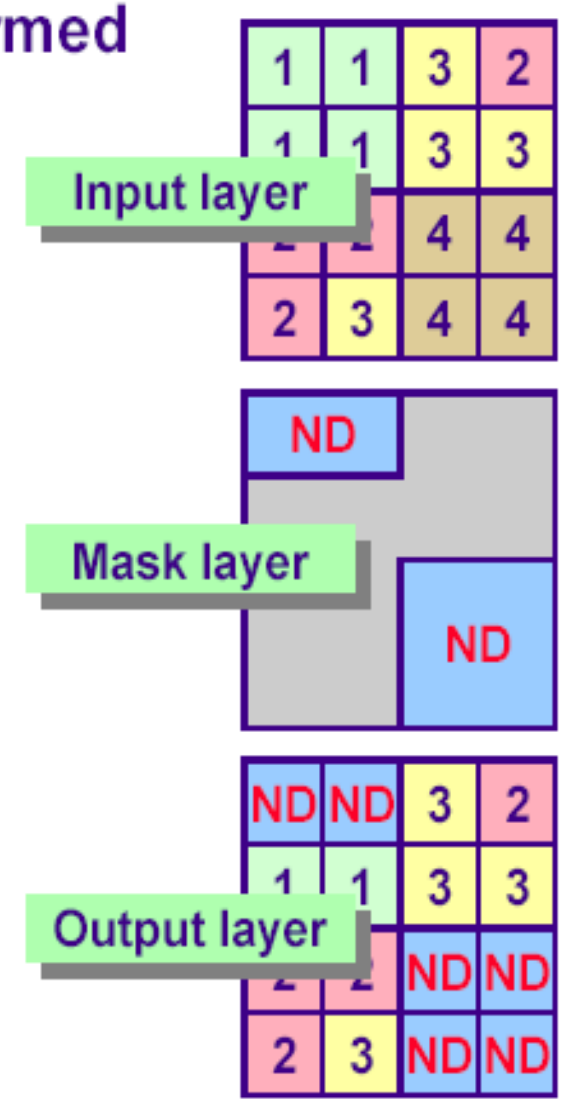
- Defines **areas where analysis is performed**
  - Useful for clipping to **irregular shapes**



Setting the analysis mask

- Define areas where analysis is performed





- NoData in mask = NoData in output
- Several ways to create a mask

Exercise 2: Raster Concepts

- **Explore** raster concepts
- **Set** the raster **analysis environment**
  - Analysis extent, cell size, mask
- **Clip** a raster dataset
  - With the analysis extent (rectangular shape)
  - With the mask (irregular shape)
- **Snap the extent** to a specific raster

Resources for Further Study

- Online Help
- Documentation
  - Using ArcGIS Spatial Analyst by Jill McCoy and Kevin Johnston
- Knowledge Base
  - http://arconline.esri.com/arconline/kbase.cfm
- Virtual Campus courses
  - http://campus.esri.com
- ArcObjects Online
  - http://arconline.esri.com/arcobjectsonline
- Online Support Center
  - http://support.esri.com

Next Topic:

Raster Representations and Calculations