Python – Raster Analysis

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GIS INSPIRING WHAT'S NEXT

Outline

- Managing rasters and performing analysis with Map Algebra
- How to access the analysis capability
  - Demonstration
- Complex expressions and optimization
  - Demonstration
- Additional modeling capability: classes
  - Demonstration
- Full modeling control: NumPy arrays
  - Demonstration

A complex model

Emerald Ash Borer

Originated in Michigan

Infest ash trees

100% kill

Coming to Vermont

The Ash Borer model

- Movement by flight
  - 20 km per year
  - Vegetation type and ash density (suitability surface)
- Movement by hitchhiking
  - Roads
  - Camp sites
  - Mills
  - Population
  - Current location of the borer (suitability surface)
- Random movement

Typical problem just like yours: The Characteristics

- Complex
- Multiple input types
  - Need to work with rasters along with features and tables
- Scenarios
  - Repeat analysis by using different parameter values
- Dynamic
  - Time is explicit, need to run sections multiple times
- Enhanced capabilities
  - Need to take advantage of 3rd party Python packages
- Reusable
  - Repeat the workflow with the same or different set of data
- Performance and optimization

Ideal for Map Algebra and Python scripting

The Ash Borer model

- Prepare the data
- An iterative model – based on a year
- Three sub models run individually each iteration and the results are combined
  - Movement by flight (run 3 different seasons)
  - Movement by hitchhiking (run once)
  - Random movement (run once)

Raster analysis – Preparing the data

- To prepare and manage raster data
  - Displaying
  - Adding, copying, deleting, etc.
  - Mosaic, Clip, etc.
  - Raster object
  - NumPy, ApplyEnvironment, etc.
- To perform analysis
  - Spatial Analyst
  - Map Algebra

What is Map Algebra

- Simple and powerful algebra to execute Spatial Analyst tools, operators, and functions to perform geographic analysis
- The strength is in creating complex expressions
- Available through Spatial Analyst module
- Integrated in Python (all modules available)

Importing Spatial Analyst

- Module of ArcPy site package
- Like all modules must be imported
- To access the operators and tools in an algebraic format the imports are important

```
import arcpy
from arcpy import env  # Analysis environment
from arcpy.sa import *
```

General syntax

- Map Algebra available through an algebraic format
- Simplest form: output raster is specified to the left of an equal sign and the tool and its parameters on the right

```
from arcpy.sa import  *
outRas = Slope(indem)
```

- Comprised of:
  - Input data
  - Tools
  - Output
  - Operators
  - Parameters

Input for analysis

- Rasters
- Features
- Numbers and text

- Objects
- Constants
- Variables

Tip: It is good practice to set the input to a variable and use the variable in the expression. Dataset names are quoted.

```
inRaster1 = "C:/Data/elevation“

outRas = Slope(inRaster1)
```

Map Algebra operators

- Symbols for mathematical operations
- Many operators in both Python and Spatial Analyst

```
outRas = inRaster1 + inRaster2
```

- Creating a raster object (Raster class constructor - casting) indicates operator should be applied to rasters

```
elevMeters = Raster("C:\data\elevation") * 0.3048
outSlope = Slope(elevMeters)
```

Map Algebra tools

- All Spatial Analyst tools are available (e.g., Sin, Slope, Reclassify, etc.)

```
outRas = Aspect(inRaster)
```

- Can use any Geoprocessing tools

Tip: Tool names are case sensitive

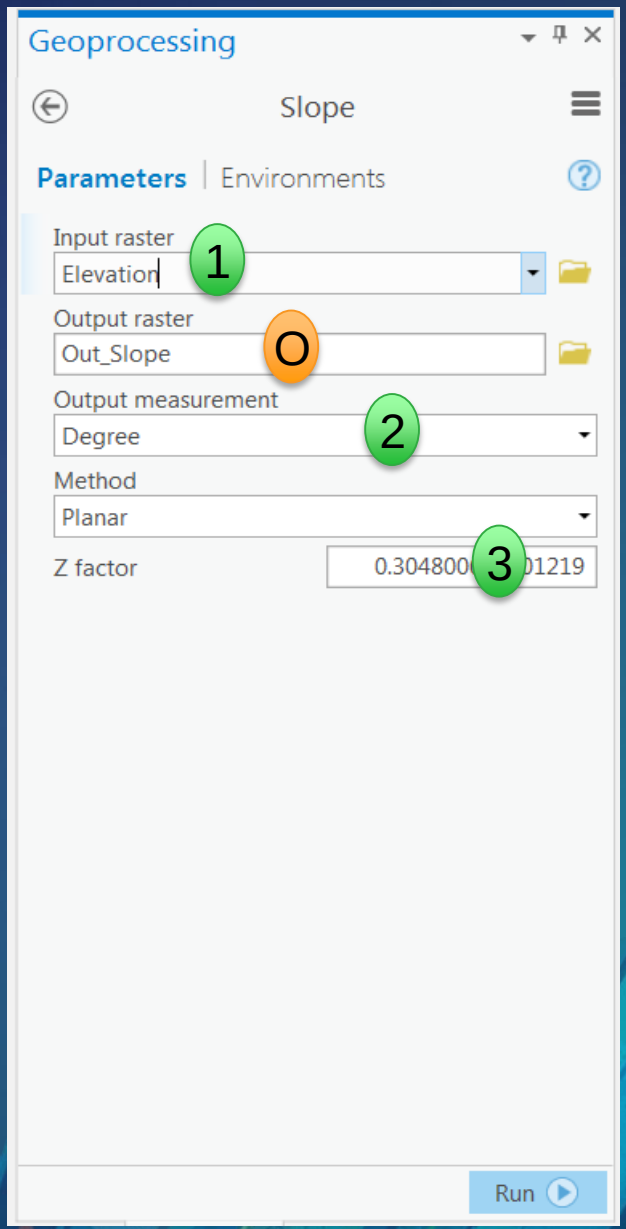
Tool parameters

- Defines how the tool is to be executed
- Each tool has its own unique set of parameters
- Some are required, others are optional
- Numbers, strings, and objects (classes)

1 2 3

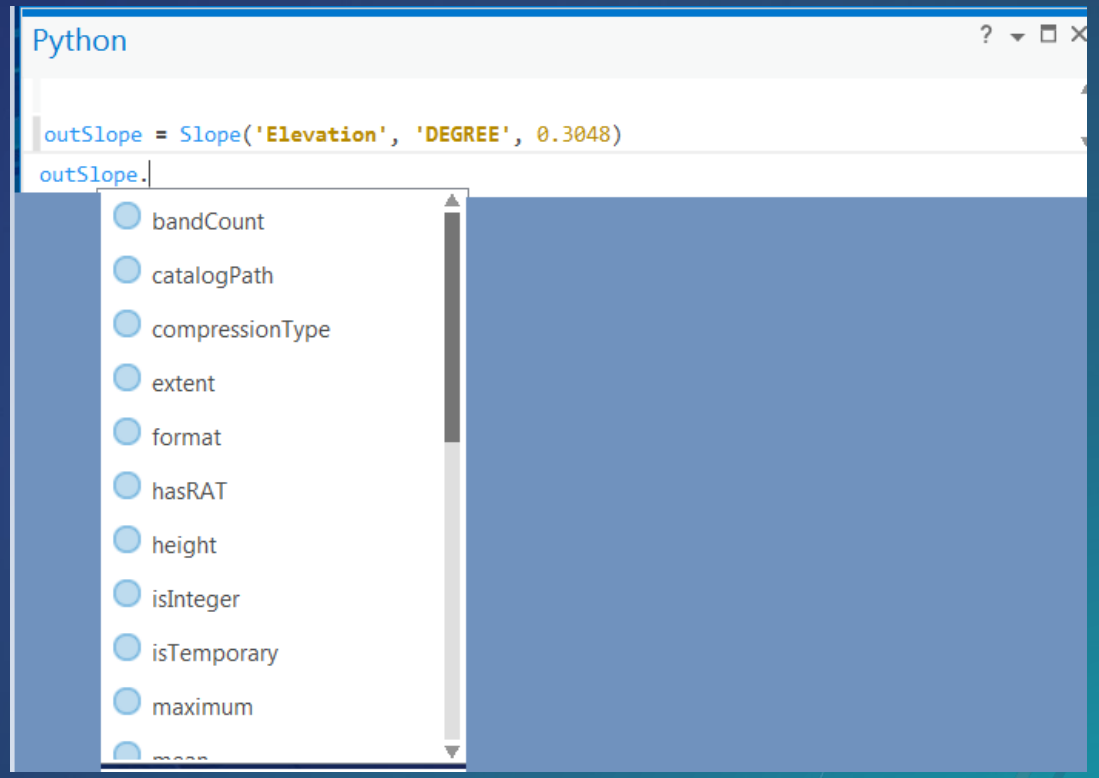
```
Slope(in_raster, {output_measurement}, {z_factor})
O outRas = Slope(inRaster, “DEGREE”, 0.3048)
outRas = Slope(inRaster, “”, 0.3048)
outRas = Slope(inRaster)
```

Tip: Keywords are in quotes



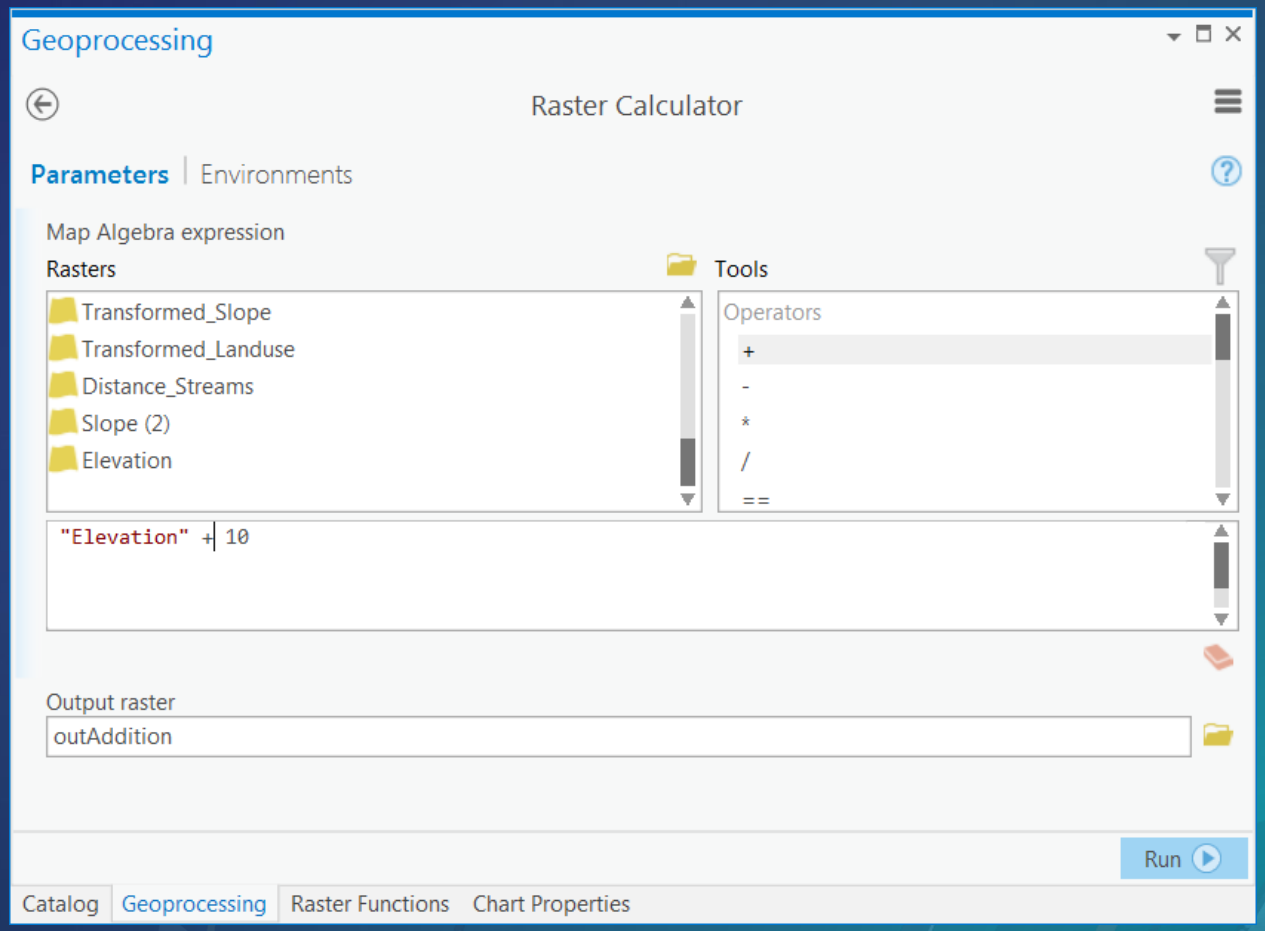
Map Algebra output

- Stores the results as a **Raster object**
- Object with methods and properties
- In scripting the output is **temporary**
- Associated data will be deleted if not explicitly saved



Access to Map Algebra

- Raster Calculator
  - Spatial Analyst tool
  - Easy to use calculator interface
  - Stand alone or in ModelBuilder
- Python window
  - Single expression or simple exploratory models
- Scripting
  - Complex models
  - Line completion and colors



The Ash Borer model

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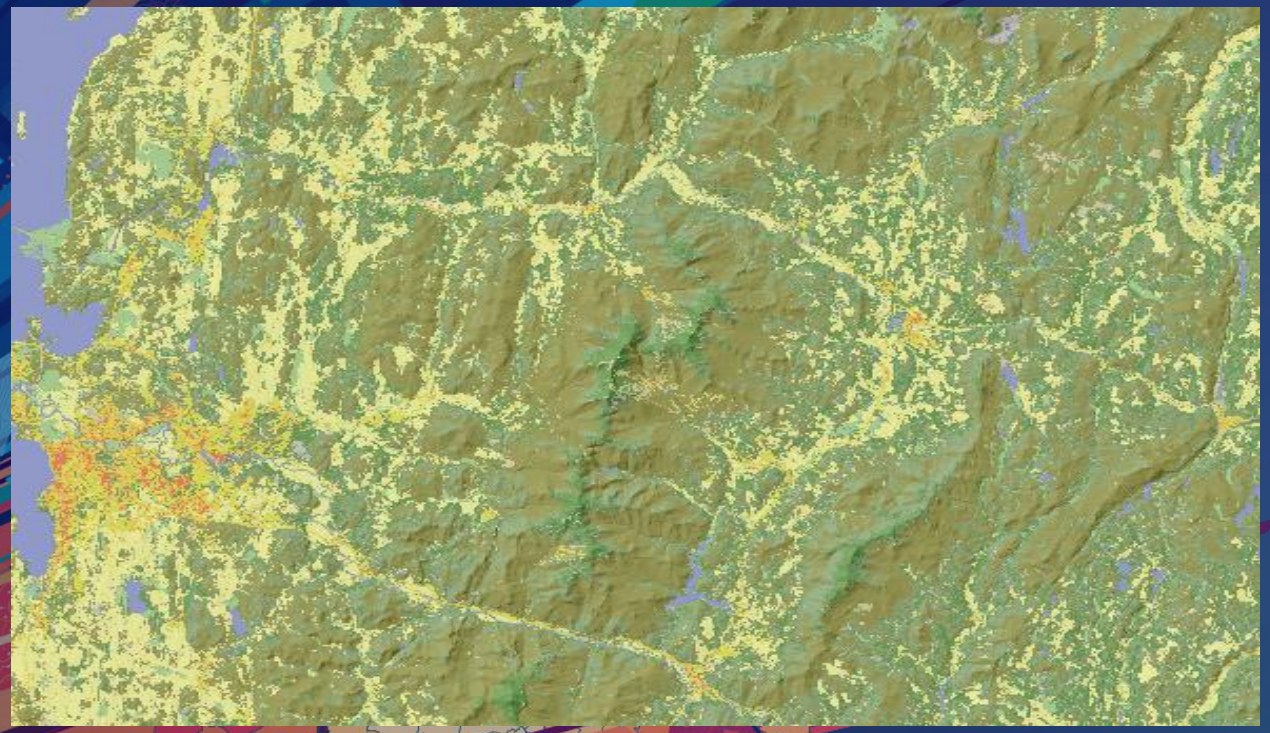

Data management and accessing the capability

Raster management tools
Raster Calculator
Python window
Model Builder
Simple expression

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Complex expressions

- Multiple operators and tools can be implemented in a single expression
- Output from one expression can be input to a subsequent expression

```
inRaster = ExtractByAttributes(inElevation, "Value > 1000")
out = Con(IsNull(inRaster), 0, inRaster)
```

More on the raster object

- A **variable** with a pointer to a dataset
- Output from a Map Algebra expression or from an existing dataset
- The associated dataset is **temporary** (from Map Algebra expression) - has a save method

```
outRas = Slope(inRaster)
outRas.save("sloperaster")
```

- A series of properties describing the associated dataset
  - Description of raster (e.g., number of rows)
  - Description of the values (e.g., mean)

Optimization

- A series of local tools (Abs, Sin, CellStatistics, etc.) and operators can be optimized
- When entered into a single expression each tool and operator is processed on a per cell basis

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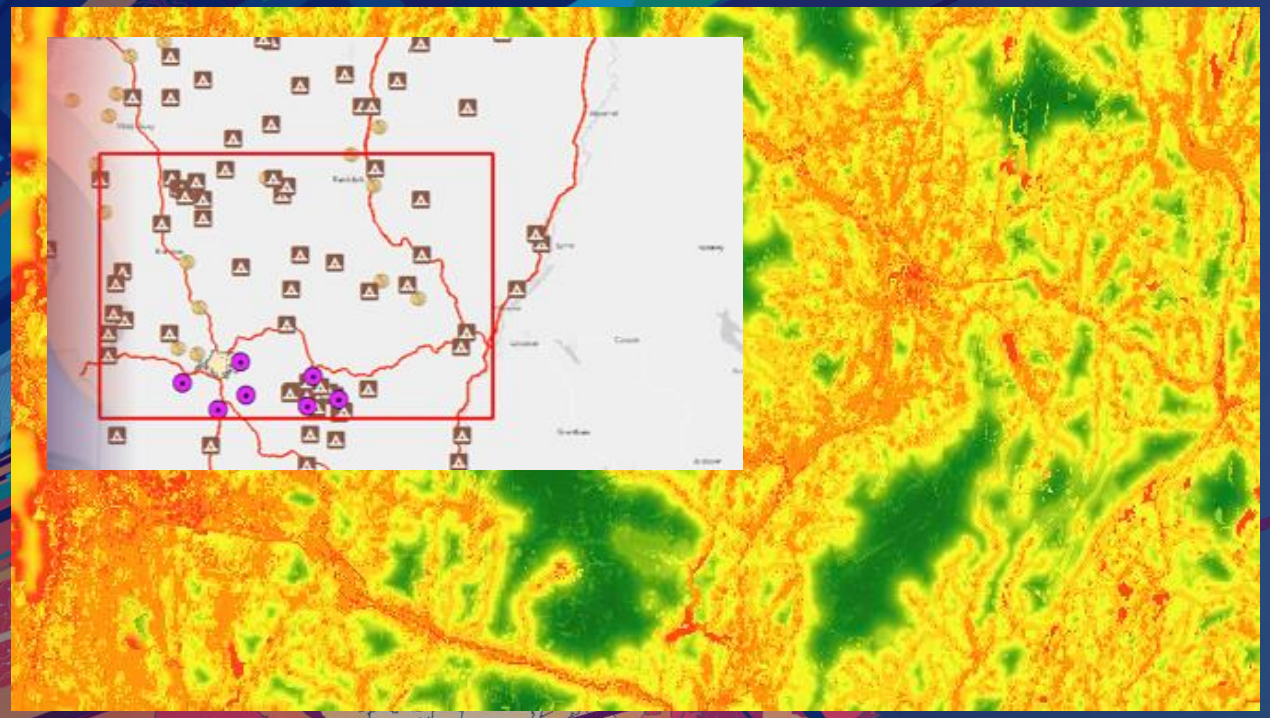
Movement by hitchhiking

- Hitchhike on cars and logging trucks
- Most likely spread around
  - Roads
  - Populated areas (towns and camp areas)
  - Commercial area (mills)
- Have a susceptibility surface
  - Vegetation types and density of ash
  - Nonlinear decay
- Random points and check susceptibility



Movement by hitchhiking

Roads, campsites, mills, population, and current location (suitability)
Complex expressions
Raster object
Optimization

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Classes

- Objects that are used as parameters to tools
  - Varying number of arguments depending on the parameter choice (neighborhood type)
  - The number of entries can vary depending on situation (remap table)
- More flexible
- Query the individual arguments

Syntax

NbrRectangle ({width}, {height}, {units})

Parameter	Explanation	Data Type
width	The width of the rectangle neighborhood. If only the `width` is specified, the resulting neighborhood is a square. (The default value is 3)	Double
height	The height of the rectangle neighborhood. If only the `height` is specified, the resulting neighborhood is a square. (The default value is 3)	Double
units	Defines the units of the neighborhood. • CELL —The unit of measurement is in cells. • MAP —The units are in map coordinates. (The default value is CELL)	String

Properties

Property	Explanation	Data Type
width (Read and Write)	The width of the rectangle neighborhood. If only the `width` is specified, the `height` will default to the same as the `width`, resulting in a square neighborhood.	Double
height (Read and Write)	The height of the rectangle neighborhood. If only the `height` is specified, the `width` will default to the same as the `height`, resulting in a square neighborhood.	Double
units (Read and Write)	Defines the units of the neighborhood.	String

Classes - Categories

- General
  - Fuzzy
  - Horizontal Factor
  - KrigingModel
  - Neighborhood
  - Time
  - Vertical Factor
  - Radius
  - Transformation functions
- Composed of lists
  - Reclass
  - Topo
  - Weighted reclass tables

General classes - Capability

- Creating

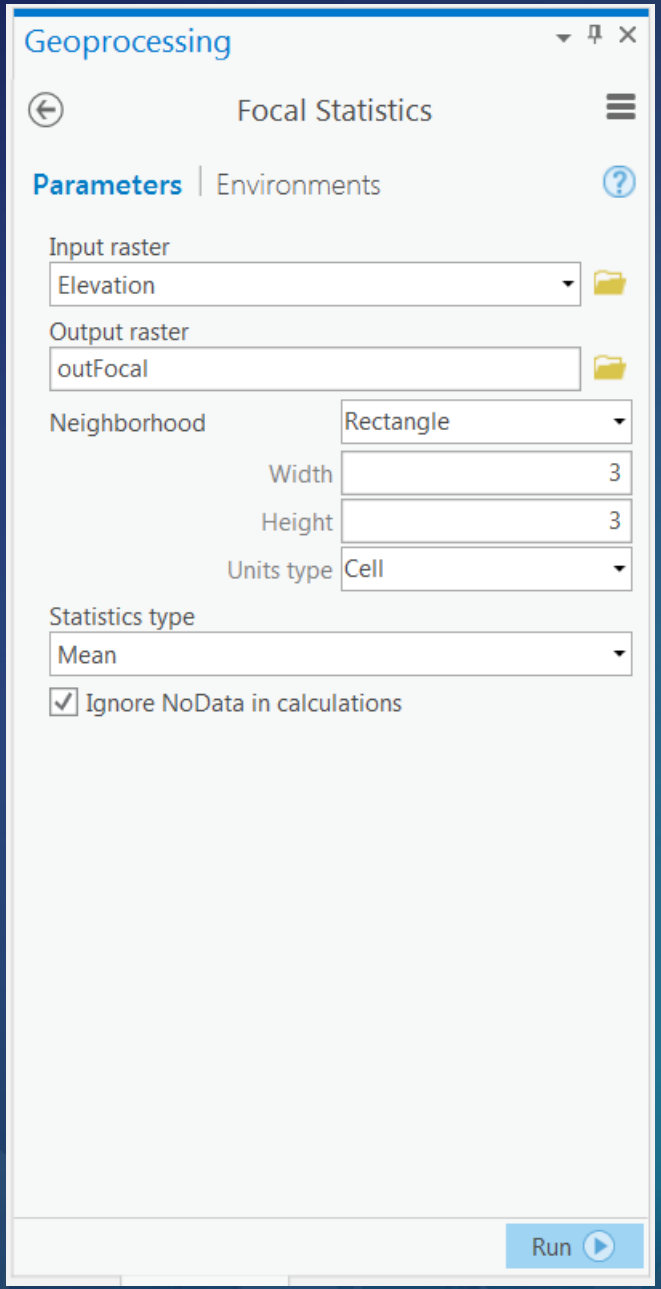
```
neigh = NbrCircle(4, "MAP")
```

- Querying

```
radius = neigh.radius
```

- Changing arguments

```
neigh.radius = 6
```



Classes composed of lists

- **Topo**

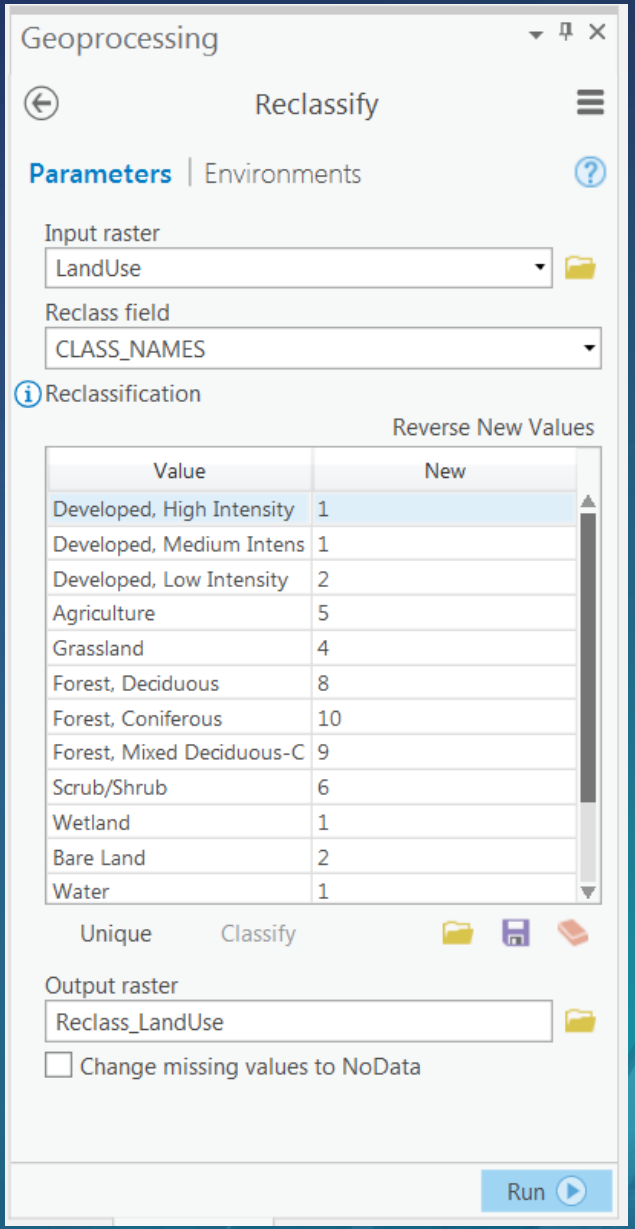
```
inContours = TopoContour([['contours.shp', 'spot_meter']])
```

- **Reclassify**

```
remap = RemapValue([["Brush/transitional", 0],
    ["Water", 1],["Barren land", 2]])
```

- **Weighted Overlay**

```
myWOTable = WOTable([[inRaster1, 50, "VALUE", remapsnow],
    [inRaster2, 20, "VALUE", remapland],
    [inRaster3, 30, "VALUE", remapsoil] ], [1, 9, 1])
```



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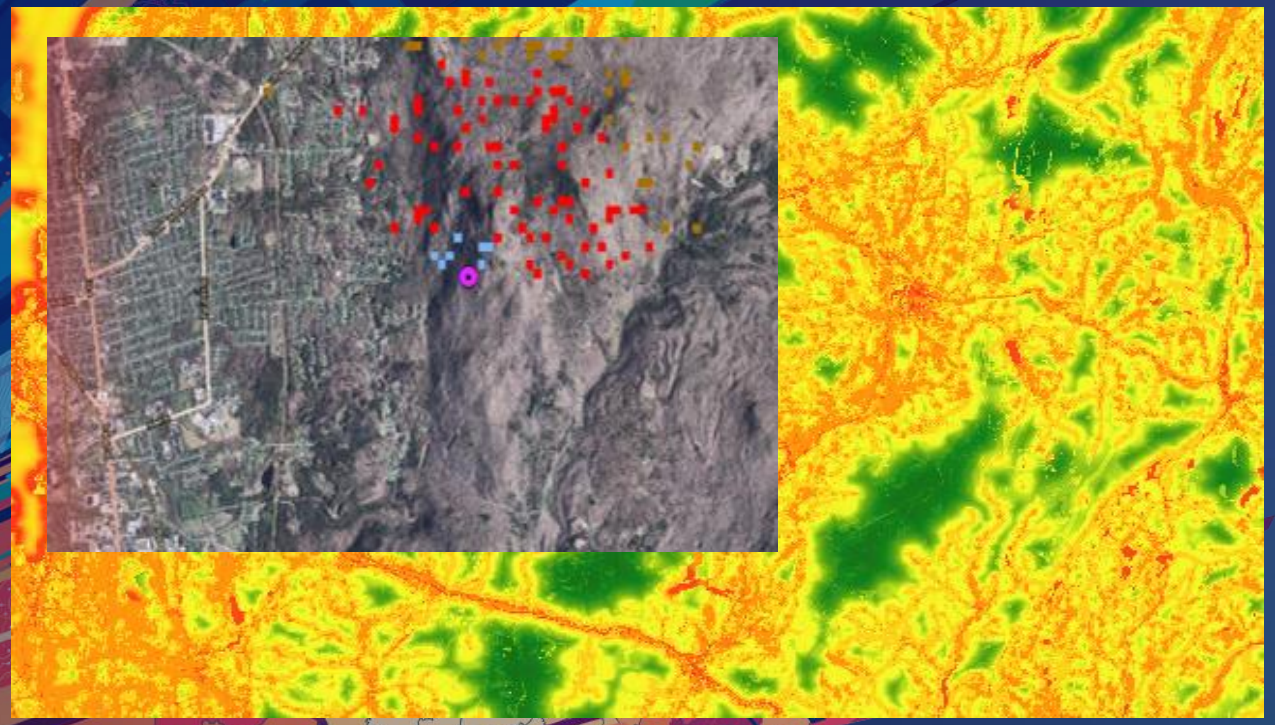
Movement by flight

- Fly from existing locations - 20 km per year
- Based on iterative time steps
  - Spring, summer, fall, and winter
- Time of year determines how far it can move in a time step
- Suitability surface based on vegetation type and ash density
- Iterative movement logic
  - “Is there a borer in my neighborhood”
  - “Will I accept it” – suitability surface



Movement by flight

20 km per year
Vegetation type/ash density (suitability)
Classes
Using variables
Vector integration

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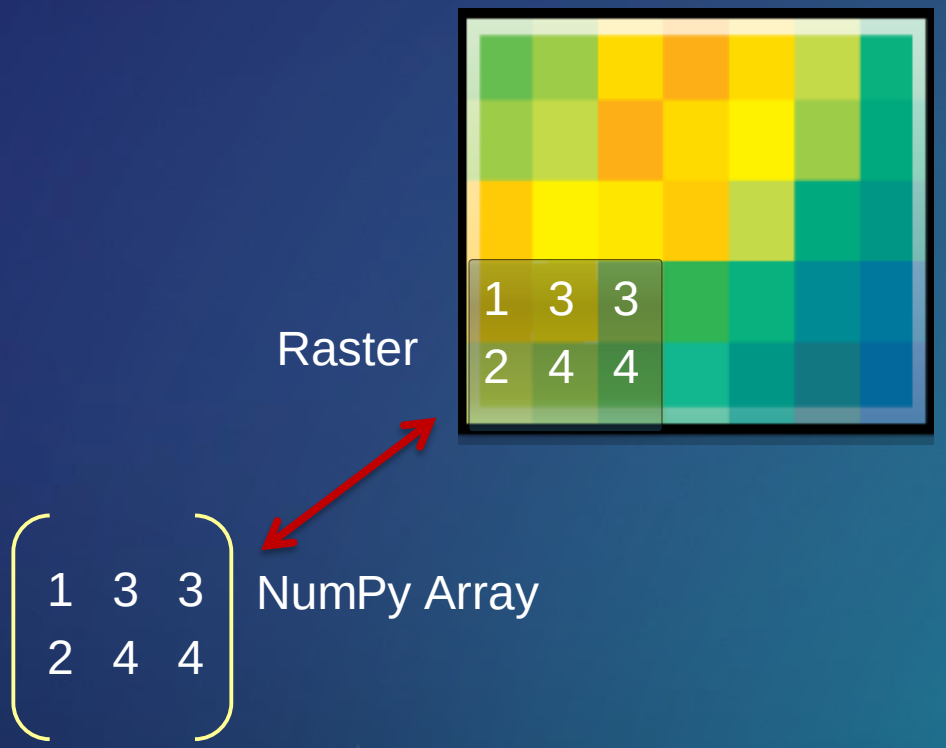
NumPy Arrays

- A generic Python storage mechanism
- Create custom tool
- Access the wealth of free tools built by the scientific community
  - Clustering
  - Filtering
  - Linear algebra
  - Optimization
  - Fourier transformation
  - Morphology

NumPy Arrays

- **Two tools**
  - **RasterToNumPyArray**
  - **NumPyArrayToRaster**



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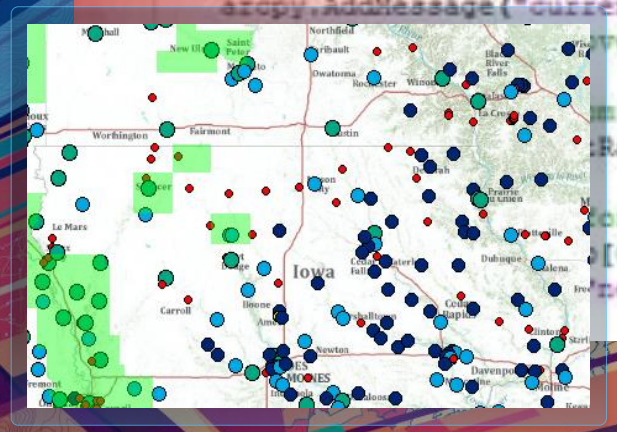
Random movement

- Some of the movement cannot be described deterministically
- Nonlinear decay from known locations
- Specific decay function not available in ArcGIS
- NumPy array
  - Export raster
  - Apply function
  - Import NumPy array back into a raster
- Return to ash borer model and integrate three movement sub models

```
def randomABMovment(arrayABlocs, arrayABsus, maxDist):
    #Get current Ash Borer locations from array (1 = infested; 0 = not in
    ABlocations = getABlocations(arrayABlocs)
    #Reduce array for every third
    ABlocations3 = ABlocations[0][::3],ABlocations[1][::3]
    nlocs = len(ABlocations3[0])
    #for each input AB location
    for i in range(nlocs):
        p = ABlocations3[0][i],ABlocations3[1][i]
        arcpy.AddMessage("current location: %s" %(str(p)))
        vements

        m movement distance.
        RandomXYDist(maxDist)

        or Ash Borer movement
        [0] - randomXYdist[0], p[1] + randomXYdist[
        new location %s" %(str(ABlocation_new)))
```



Random movement

Random movement based on nonlinear decay from existing locations

Custom function

NumPy array

Summary

- When the problem becomes more complex you may need additional capability provided by Map Algebra
- Map Algebra powerful, flexible, easy to use, and integrated into Python
- Accessed through: Raster Calculator, Python window, ModelBuilder (through Raster Calculator), and scripting
- Raster object and classes
- Create models that can better capture interaction of phenomena

Additional resource

- **Suitability modeling case study**

http://desktop.arcgis.com/en/analytics/case-studies/understanding-the-suitability-modeling-workflow.htm

- **Cost distance analysis case study**

http://desktop.arcgis.com/en/analytics/case-studies/understanding-cost-distance-analysis.htm

- **Spatial Analyst Resources**

https://www.esri.com/arcgis-blog/products/arcgis-pro/analytics/spatial-analyst-resources/

- **Raster Analysis and Spatial Analyst Sessions at UC 2018**

https://www.esri.com/arcgis-blog/products/spatial-analyst/announcements/uc2018-spatial-analyst-raster-analysis/

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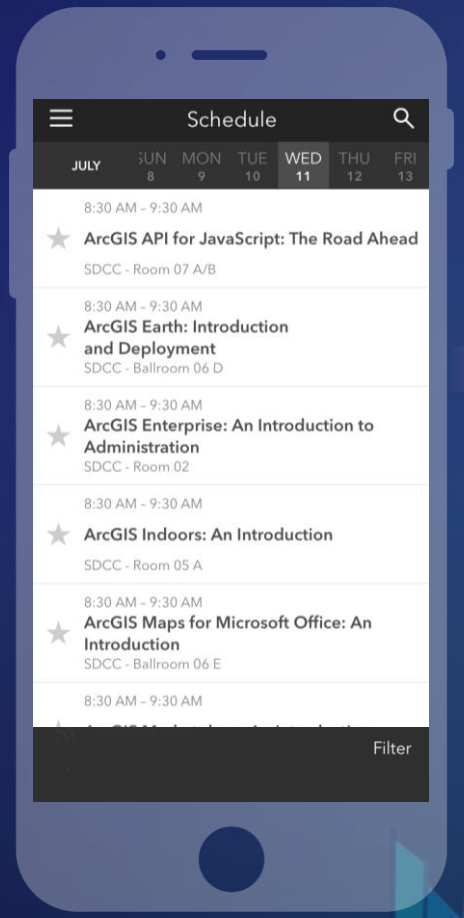

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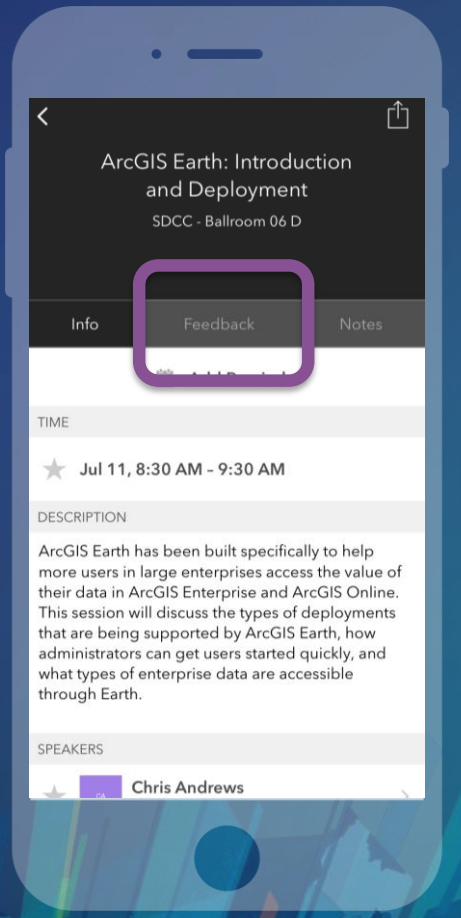
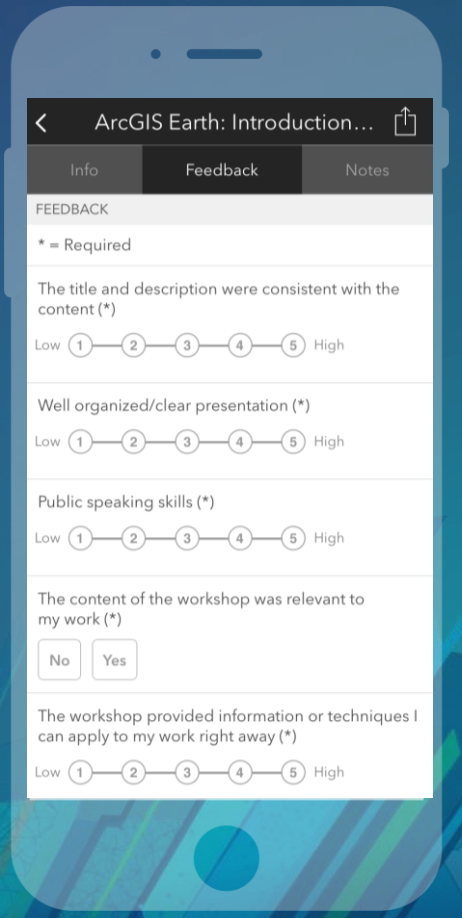


Complete answers and select “Submit”



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