

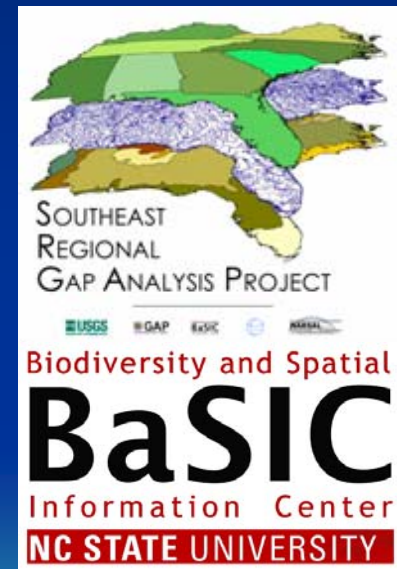
# Methods for Generating Patch and Landscape Metrics

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Conservation Design Workshop  
St. Louis, MO April 11, 2006



# What Are Landscape and Patch Metrics?

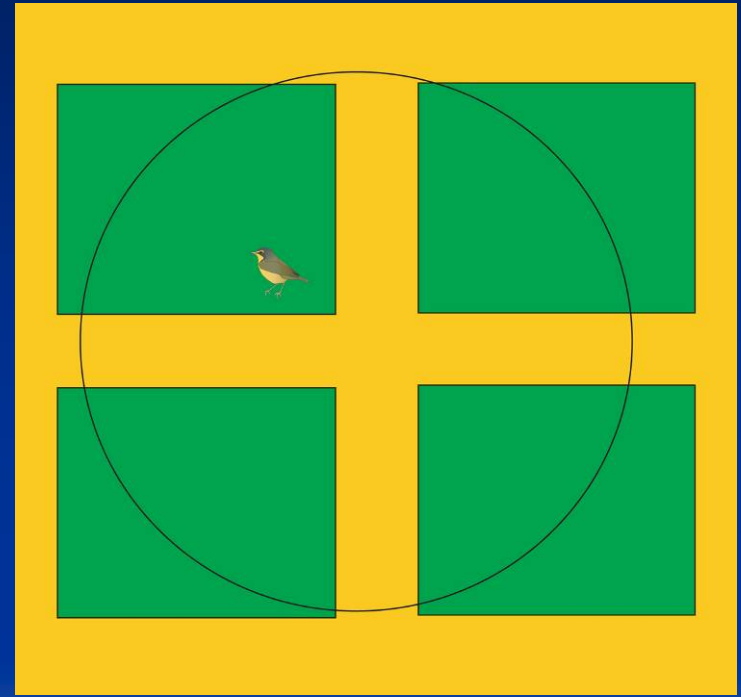
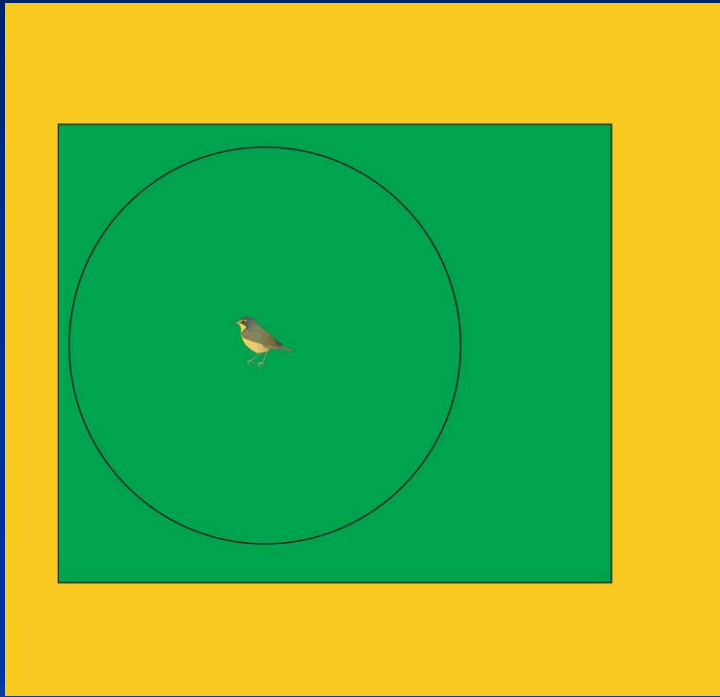
- Algorithms for quantifying spatial heterogeneity.
- Efforts to measure landscape patterns are often driven by the premise that patterns are linked to ecological processes

Edges → Predation

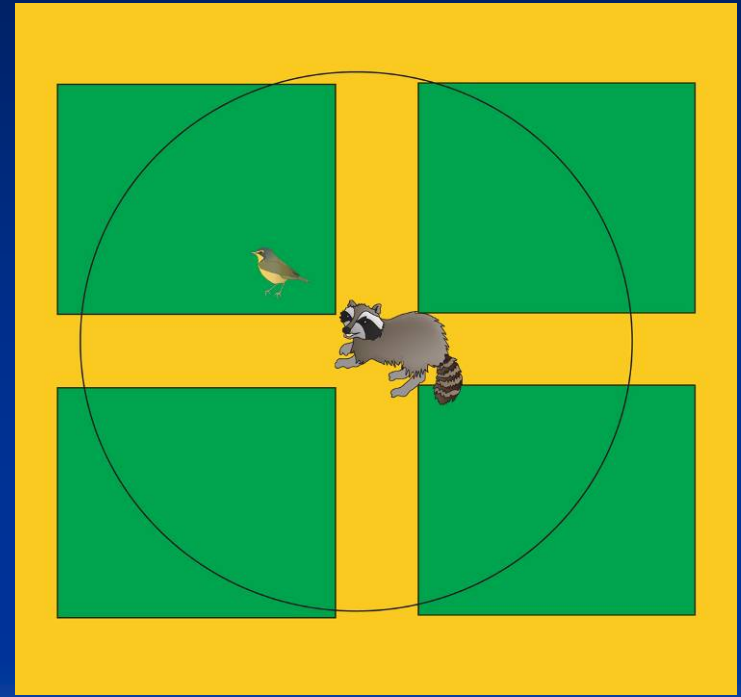
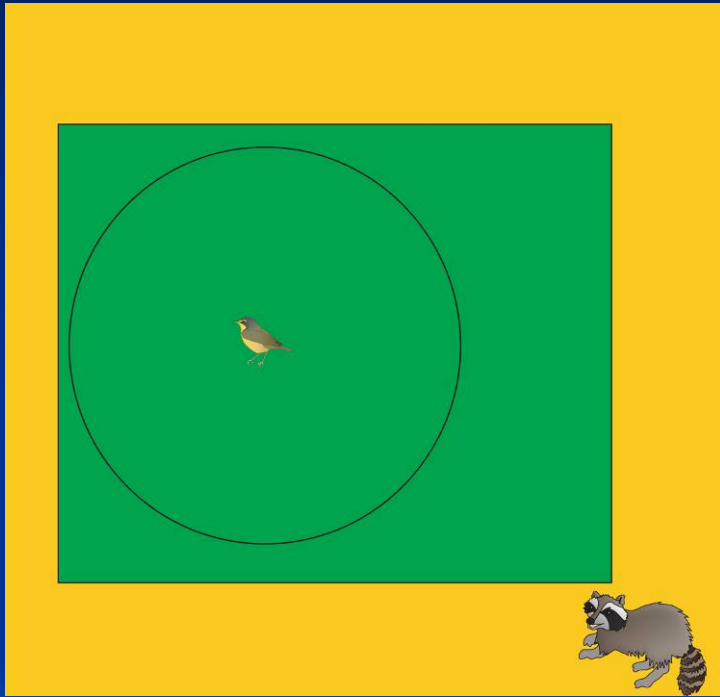
Fragmentation → Energy Expenditure



# Pattern-Process



# Pattern-Process



# Why Are Landscape and Patch Metrics Useful?

- More and more maps are becoming available for pattern-process predictions over large areas
- Permit a coarse approximation of various landscape processes
- Faster and less expensive than extensive surveys
- Facilitate efficient sampling for research and monitoring
- Many more...



# Definitions

- **Landscape:** “Area that is spatially heterogeneous in at least one factor of interest.”
- **Patch:** “Surface area that differs from its surroundings in nature or appearance.”
- **Scale:** “...the spatial or temporal dimension of an object or a process.”
  - **Grain:** Smallest sampling unit (e.g., 30m pixel)
  - **Extent:** Entire area or time of consideration (e.g., a study region or state)
- **Level:** “...a place within a biotic hierarchy” or a relative precision of pattern characterization.

Turner et al. 2001. Landscape Ecology in Theory and Practice. Springer-Verlag



# Examples of Metrics

- Patch metrics: summarize the shape or size of patches
  - Area, perimeter, width
  - Core area: requires a threshold distance to edge
- Landscape metrics: quantify the spatial relationships among patches within the landscape
  - Composition
    - Fractional Cover: what proportion of the landscape is occupied by a given class
    - Richness: the number of classes
    - Evenness: the relative abundance of classes
  - Configuration
    - Contagion and Dispersion: distinguish between landscapes with clumped or evenly distributed patches
    - Isolation: based on the distances between similarly classified patches
- Neighbor metrics: quantify spatial relationships among objects
  - Calculate distances between similarly classified features (patches, lines)
  - Quantify distance road or water (distance to edge can be difficult)



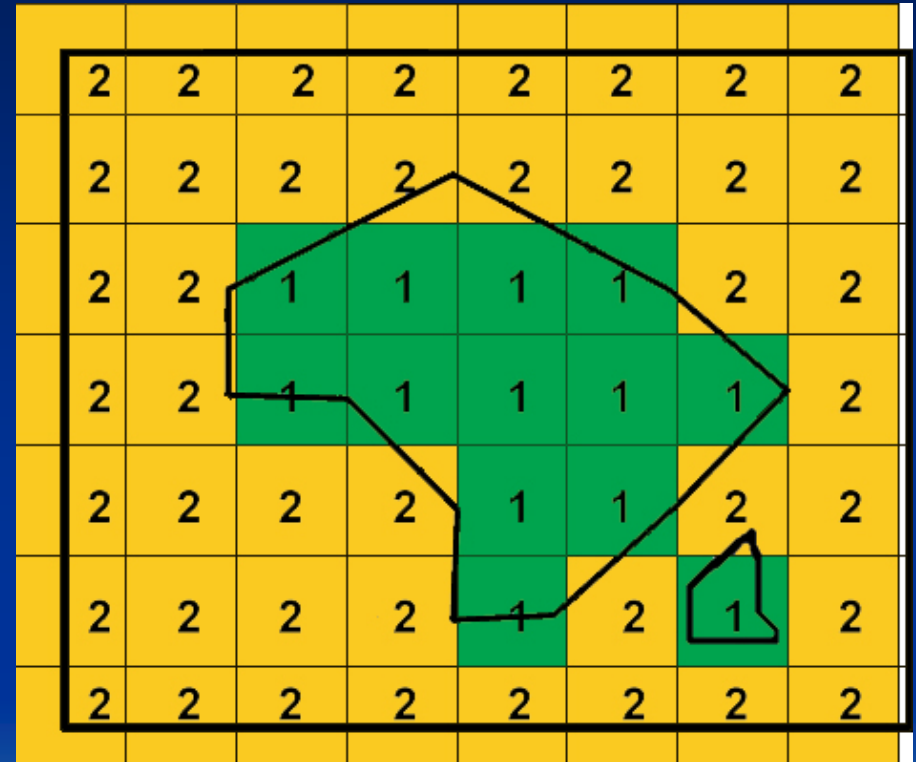
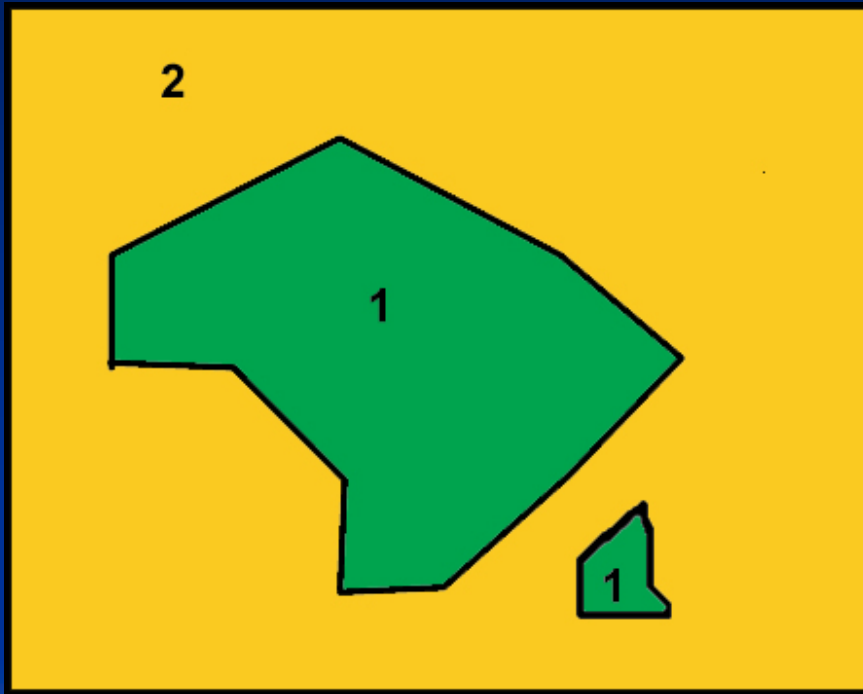
# Data Types

- **Vector:** each object explicitly represented as points, lines or polygons.
  - Pros: small files; permits topology (i.e., explicit spatial relationships between connecting or adjacent objects)
  - Cons: complex data structure (Slow!); can require much more time to create; manipulations require complex algorithms
- **Raster:** data is divided into a grid consisting of individual cells or pixels. Each cell holds a numeric (e.g., elevation in meters) or descriptive (e.g., land use) value.
  - Pros: simple data structure; easy to represent continuous variables (e.g., intensity); filtering and mathematical modeling is relatively simple
  - Cons: Large files; no topology; objects are generalized (limited by cell size)

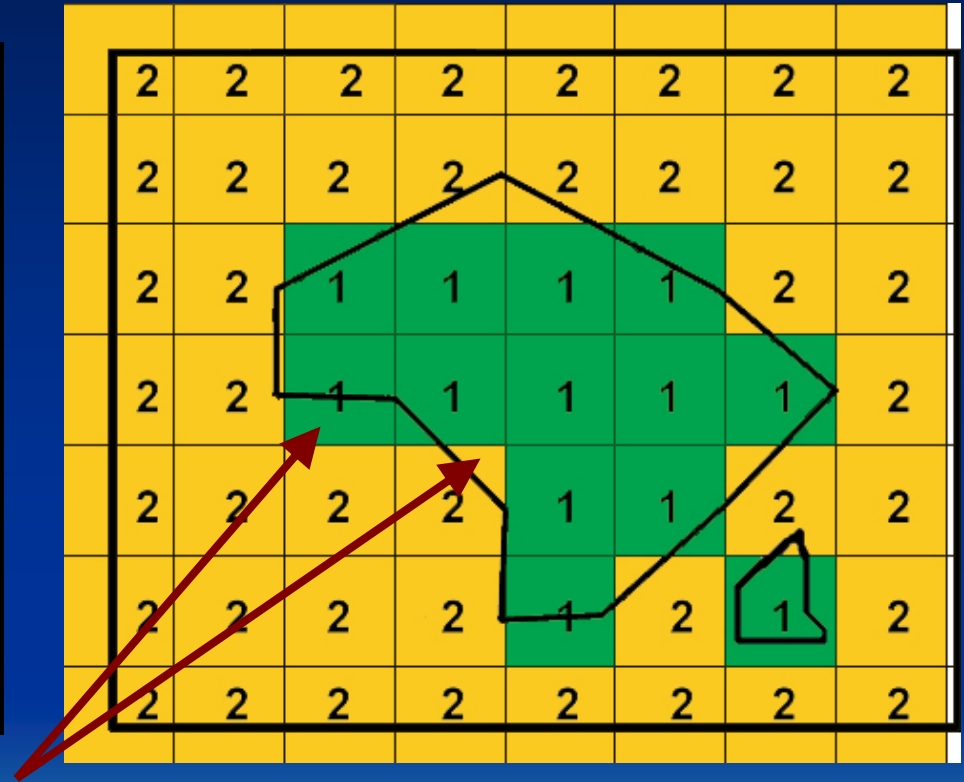
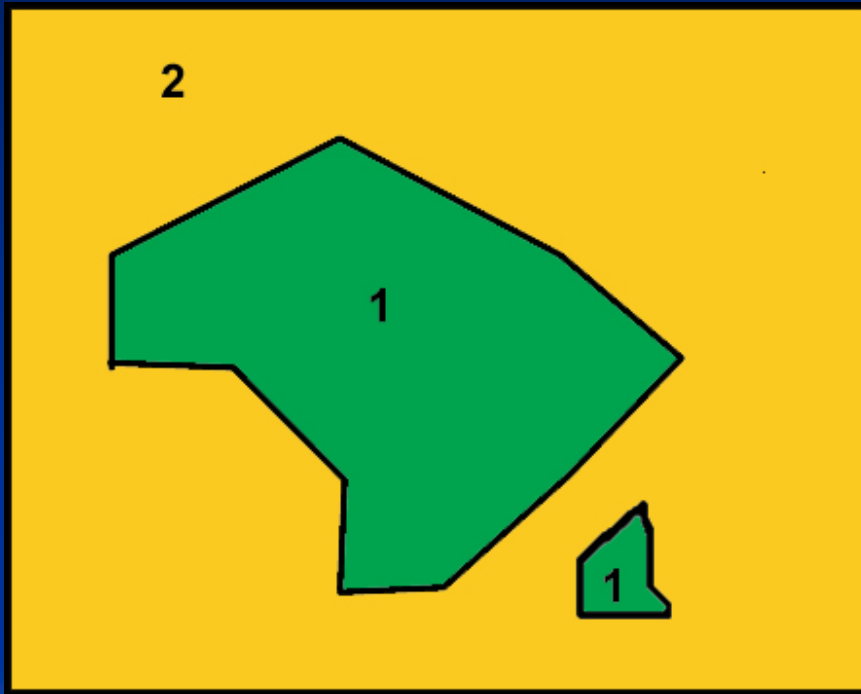




# Vector vs. Raster

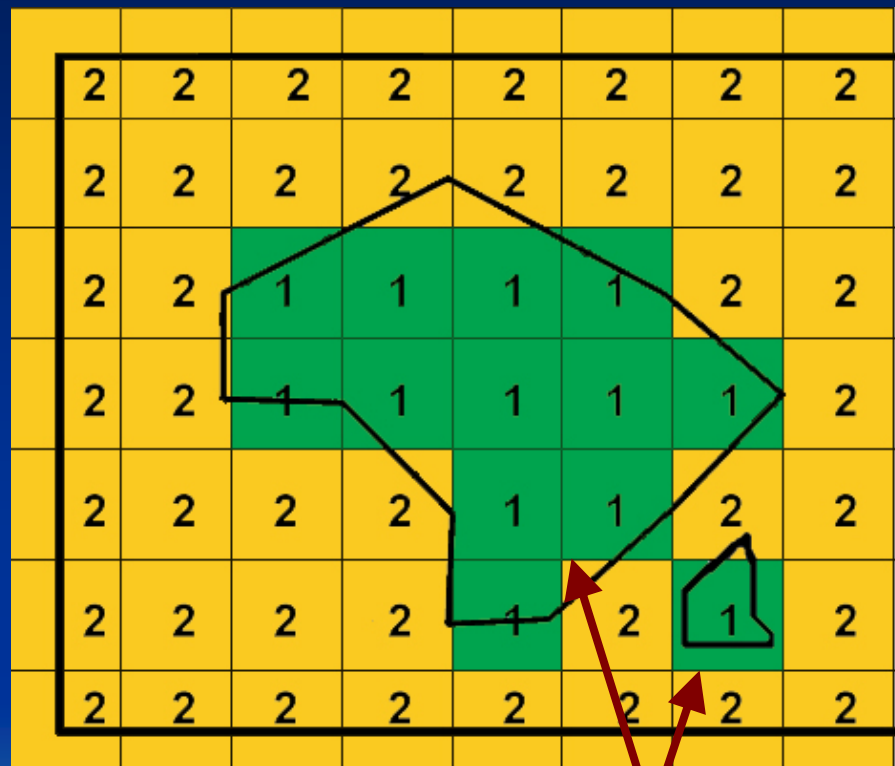
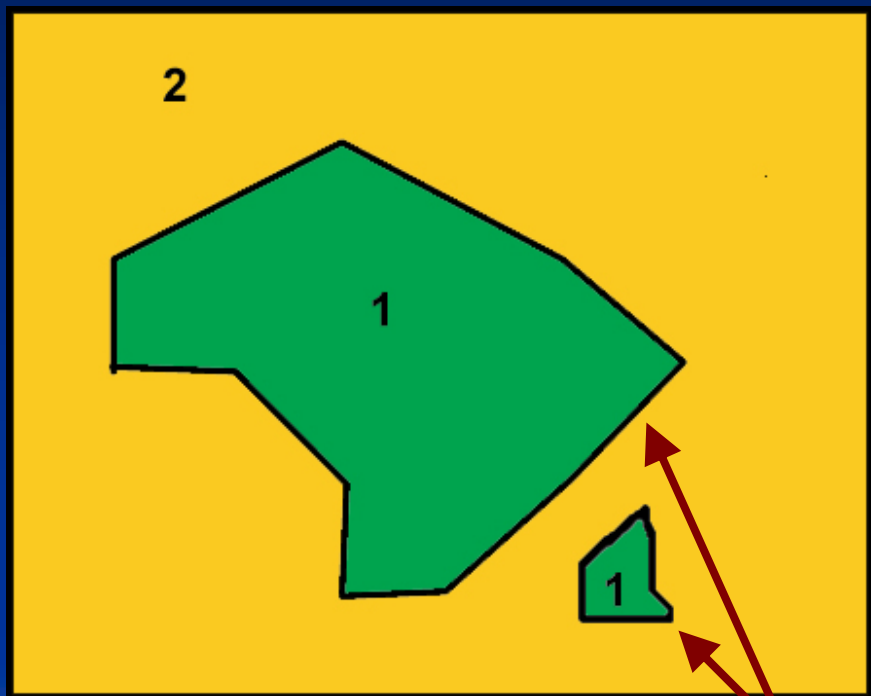


# Vector vs. Raster



Inaccuracies due to less spatial precision

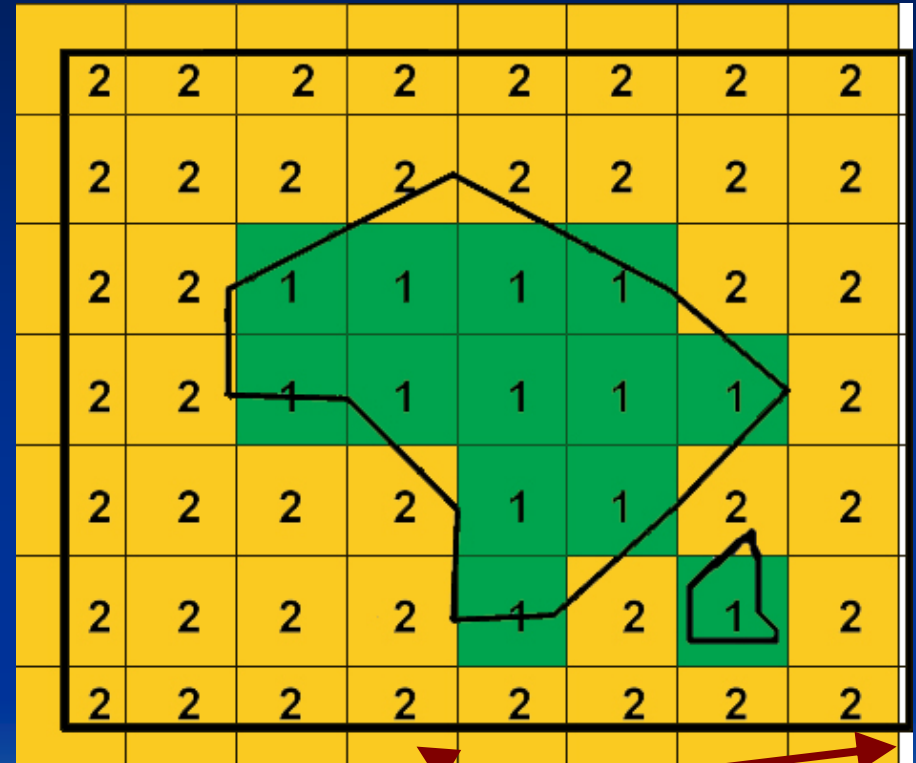
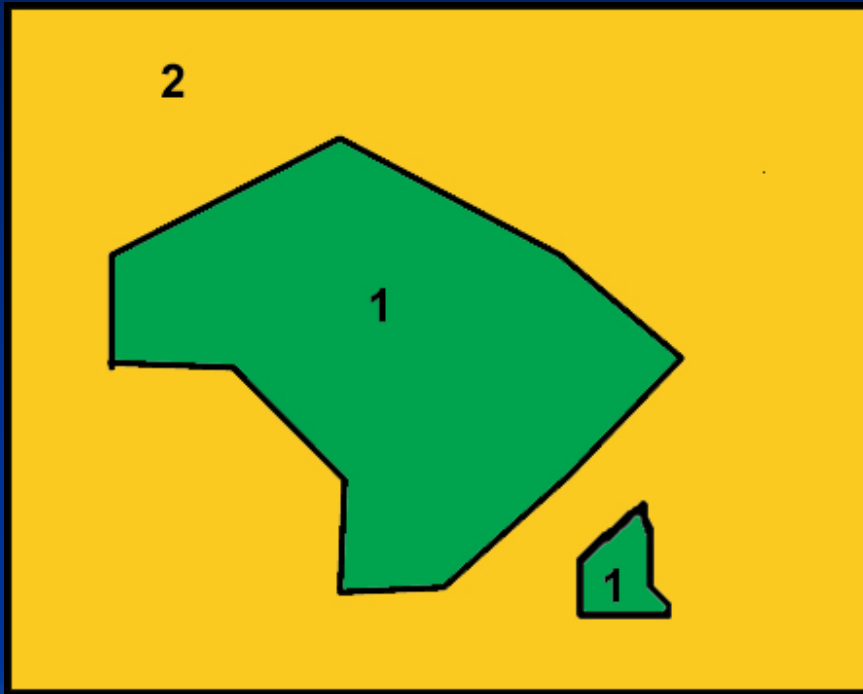
# Vector vs. Raster



Explicitly defined  
as two objects

Two objects?

# Vector vs. Raster



Shift in study  
region boundary

# Software

- Stand alone

- Various GIS & RS packages (e.g., ArcGIS, GRASS, Imagine)
- FRAGSTATS <http://www.umass.edu/landeco/research/fragstats/fragstats.html>
- APACK <http://landscape.forest.wisc.edu/projects/apack/>
- IAN <http://landscape.forest.wisc.edu/projects/IAN/>

- GIS extensions

- Patch Analyst for ArcView 3.x <http://flash.lakeheadu.ca/~rrempe/patch/>
- r.le programs that interface with GRASS



# Anthropocentric vs. Functional Landscape Descriptions

*“...the choice of categories to include in a pattern analysis is critical.”*  
(Turner et al. 2001)

- **Anthropocentric:** human defined landscape heterogeneity
  - How would you divide the landscape?
  - Data limitations (e.g., sensor resolution, spectral variability)
- **Functional:** Heterogeneity defined by the process of interest
  - Example: descriptions that reflect how other species' behaviors or population rates differ across the landscape
  - Knowledge limitations

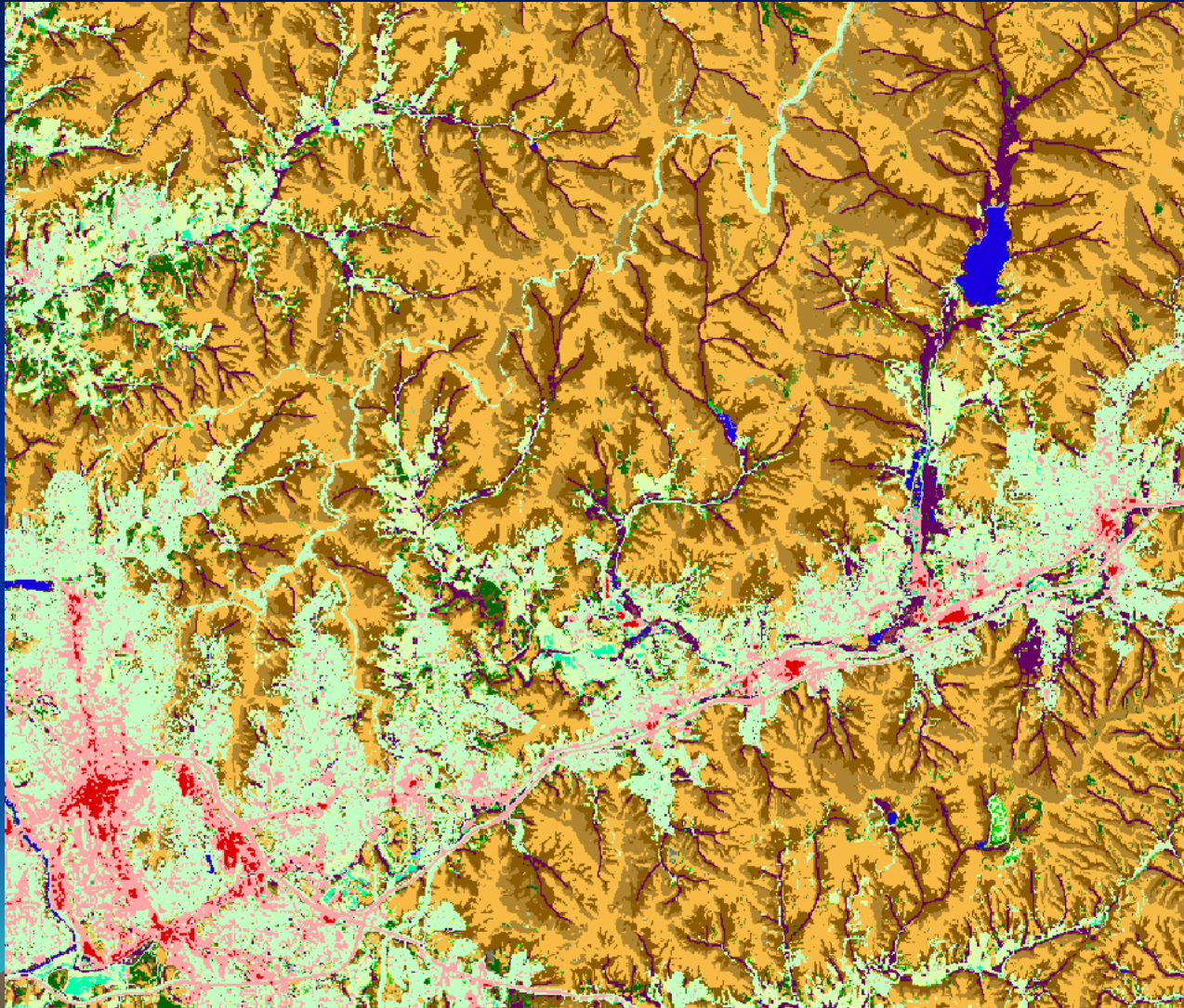


# Crosswalk Anthropocentric to Functional

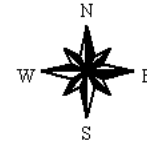
Avian Habitat Types	NC-GAP Map Units
Estuarine emergent marsh	Tidal Marsh
Open Fresh Water	Open water
Atlantic white cedar	Seepage and Streamhead Swamps
Maritime forest	Maritime Forests and Hammocks
Early-successional hardwood and pine	Coniferous Regeneration
Pine plantations	Coniferous Cultivated Plantation (natural / planted)
Cypress-tupelo	Cypress-Gum Floodplain Forests
Early-successional hardwood and pine	Successional Deciduous Forests
Atlantic white cedar	Peatland Atlantic White-Cedar Forest
Pine sandhills	Xeric Longleaf Pine
Pine hardwoods	Xeric Oak - Pine Forests
Bottomland hardwood	Coastal Plain Oak Bottomland Forest



# Avicentric Land Cover



- Avicentric classes
- Agricultural and cropland
  - Airfields/golf courses/cemeteries
  - Appalachian balds
  - Bottomland hardwood
  - Cliffs/domes/outcrops
  - Commercial urban
  - Dry mixed hardwoods
  - Early-successional hardwood and pine
  - Freshwater shrub/s scrub
  - Hemlock/white pine/hardwood
  - Manmade/disturbed
  - Mesic mixed hardwoods
  - Mixed mesophytic (cove hardwood)
  - Oak-cedar
  - Open fresh water
  - Other pine forest - natural
  - Pasture
  - Pine hardwoods
  - Rank annuals
  - Residential
  - Riparian



2 0 2 Kilometers



# Example of Documenting and Using Patch and Neighborhood Metrics by SE-GAP

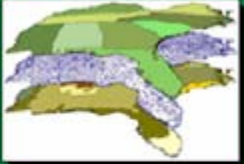
Map Algebra  
Stating Assumptions  
Sources of Errors



# Literature Review Database

Main Switchboard

**Southeastern Regional Gap Analysis Project**



**Habitat and Population Data Entry**

- Add database values
- Review database values
- Author sorted database values
- Add references
- Literature search descriptions
- Format references
- Contact and citation

Search Description : Form

Search Database: BioOne Search Name: BioOne\_ACFL

Search Date: 1/6/2006 Search Words: Acadian Flycatcher

Year Min: Year Max:

Type: Full Text, Exact Phrase #Hits: 40

Comments:

Record: 2 of 14

Citation QuickEntry : Form

ArticleID: Skipped	Search Name: Search Holder	Endnote#: 131	First author's last name: Ford	Year: 2001
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Original Citation:  
Ford, Thomas B., Winslow, Donald E., Whitehead, Donald R., Koukol, Matthew A. 2001: REPRODUCTIVE SUCCESS OF FOREST-DEPENDENT SONGBIRDS NEAR AN AGRICULTURAL CORRIDOR IN SOUTH-CENTRAL INDIANA. The Auk: Vol. 118, No. 4, pp. 864-873.


Secondary (Referencing) Citation:

Abstract:  
Potential source populations of forest-breeding Neotropical migrant birds may be threatened by anthropogenic changes that increase brood parasitism by Brown-headed Cowbirds (*Molothrus ater*) and nest predation in heavily forested breeding areas. In south-central Indiana, corridors of agriculture and rural development, ranging from <50 m to several thousand meters in width, penetrate interior portions of the heavily forested landscape. These corridors provide habitat for cowbirds and nest predators. We monitored breeding success of six species of Neotropical migrants and one resident species near an agricultural corridor and in interior forest. We found that nest survival was lower near the agricultural corridor for most of the species in the nestling stage, but no consistent difference in nest survival was detected during the egg stage. Levels of cowbird parasitism were generally elevated near the agricultural corridor. Estimates of the number of fledglings per nesting attempt indicated that seasonal productivity was lower near the agricultural corridor for six of the seven species. Status of populations of birds in south-central Indiana as sources in the Midwest may be compromised by extensive intrusion of agricultural corridors within the contiguous, heavily forested landscape.

Link:  
<http://www.bioone.org/bioone/request=get-document&issn=0004-8038&volume=118&issue=04&page=0864>

Record: 1 of 152

# Habitat Suitability

Species:	ACFL	State:	TX
Life History:	Breeding		
Cover Type:	Wet: Riparian		
Survey method:	Transect		
Importance:	Suitability:	Use:	
Low	Hostile	Avoided	
Medium	Marginal	None	
High	Suitable	Traveled	
	Optimal	Complementary	
No relationship		Substitutable	
<input type="checkbox"/>		Needed	
ArticleID:	Endnote#:	Input:	Add new input for the reference below
516	8	1	

# Landscape Modifiers

Species: ACFL State: TX

Life History: Breeding

Cover Type: Wet: Riparian

Survey method: Transect

Importance: Suitability: Use:

Low  
Medium  
High

Hostile  
Marginal  
Suitable  
Optimal

Avoided  
None  
Traveled  
Complementary  
Substitutable  
Needed

No relationship

Cover Type Modification

Categorical: Landform: Flats Wet

Continuous: Distance to water

**Set thresholds for continuous variables**

**Best**

**Optimal Low:** 70 **Optimal High:** 90

**Suitable Low:** 50 **Suitable High:** 100

**Marginal Low:** 30 **Marginal High:** [ ]

**Minimum** **Maximum**

Units: m

Response Curve: skewed left

# Spatially Explicit Population Descriptions

Species: ACFL	State: TX	
Life History: Breeding		
Cover Type: Wet: Riparian		
Survey method: Transect		
Importance: Low Medium <b>High</b>	Suitability: Hostile Marginal <b>Suitable</b> Optimal	Use: Avoided None Traveled Complementary Substitutable Needed
No relationship <input type="checkbox"/>		
Cover Type Modification		
Categorical: Landform: Flats Wet		
Continuous: Distance to water		
ArticleID: 516	Endnote#: 8	Input: 1
Add new input for the reference below		

<b>Set thresholds for continuous variables</b>	
Optimal Low: 70	Optimal High: 90
Suitable Low: 50	Suitable High: 100
Marginal Low: 30	Marginal High: [ ]
Units: m	Response Curve: skewed left
Minimum	Maximum

<b>Life History Details</b>	Return later to fill in details: <input type="checkbox"/>	InterSpecAggr: [ ]
Spacing: Abundance	Rate: [ ]	
Min: 0	Avg: 0.8	Max: 3.5
StDev: [ ]	SE: [ ]	N: 10
Units: individuals	No Effect: <input type="checkbox"/>	

Quotes to back input:

The Acadian Flycatcher (*Empidonax virescens*), Yellow-throated Vireo (*Vireo flavifrons*), and Yellow-billed Cuckoo (*Coccyzus americanus*) seemed to require at least 70 m of forest width before their abundance increased.

Input Comments:

Interpreted from Figure 1 that plots the mean number detected as a function of streamside zone width. Abundance calculated for 50m transects of 10m increments of riparian buffers but transects were of unknown width.

# Queries

Species	Rate	sMin	sAvg	sMax	Standard units	Cover Type	Categorical	Continuous
ACFL	Breeding synchrony	0.2	0.3	0.3	unitless	Wet: Riparian		
ACFL	Daily nest failure (last egg)	0.3		1.2	%	UpForest: Dry mixed hardwoods		
ACFL	Daily nest mortality	1.3	3.8	5.7	% (Mayfield corrected)	UpForest: Dry mixed hardwoods		Canopy Cover
ACFL	Daily nest predation		2.8		% (Mayfield corrected)	UpForest: Dry mixed hardwoods		
ACFL	Daily nest survival	73.0		92.0	% (Mayfield corrected)	UpForest: Dry mixed hardwoods		Stand Age
ACFL	Daily nest survival	94.7	95.6	96.5	% (Mayfield corrected)	UpForest: Dry mixed hardwoods		
ACFL	Daily nest survival		97.8		% (Mayfield corrected)	UpForest: Mesic mixed hardwood		
ACFL	Daily nest survival		94.2		% (Mayfield corrected)	Wet: Bottomland hardwood		Stand Age
ACFL	Daily nest survival	92.0	94.8	96.5	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Daily nest survival	81.8	95.1	100.0	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Daily nest survival				fledglings	UpForest: Dry mixed hardwoods		Non-contiguous Pa
ACFL	Daily survival during incubation	97.5		98.0	% (Mayfield corrected)	UpForest: Dry mixed hardwoods	Edge: Forest/Ag	Non-contiguous Pa
ACFL	Daily survival during incubation		97.6		% (Mayfield corrected)	UpForest: Mesic mixed hardwood		
ACFL	Daily survival during incubation	92.0	94.9	96.6	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Daily survival during nestling st:	93.8		96.2	% (Mayfield corrected)	UpForest: Dry mixed hardwoods	Edge: Forest/Ag	Non-contiguous Pa
ACFL	Daily survival during nestling st:		97.9		% (Mayfield corrected)	UpForest: Mesic mixed hardwood		
ACFL	Daily survival during nestling st:	91.5	94.5	97.0	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Eggs per nest		2.8		eggs	UpForest: Mesic mixed hardwood		
ACFL	Eggs per nest	1.0	2.5	4.0	eggs	Wet: Riparian		
ACFL	Extrapair young		41.0		%	Wet: Riparian		

Each record is one entry in the previous form

# Map Algebra

Logistic (S-shaped)

$$1 / (1 + a * \text{EXP}(- b * ([\text{Map Value}] / c)))$$

Example:  $1 / (1 + 40 * \text{EXP}(- 6 * ([\text{Dist\_Edge}] / 90)))$

**a** affects where upturn begins.

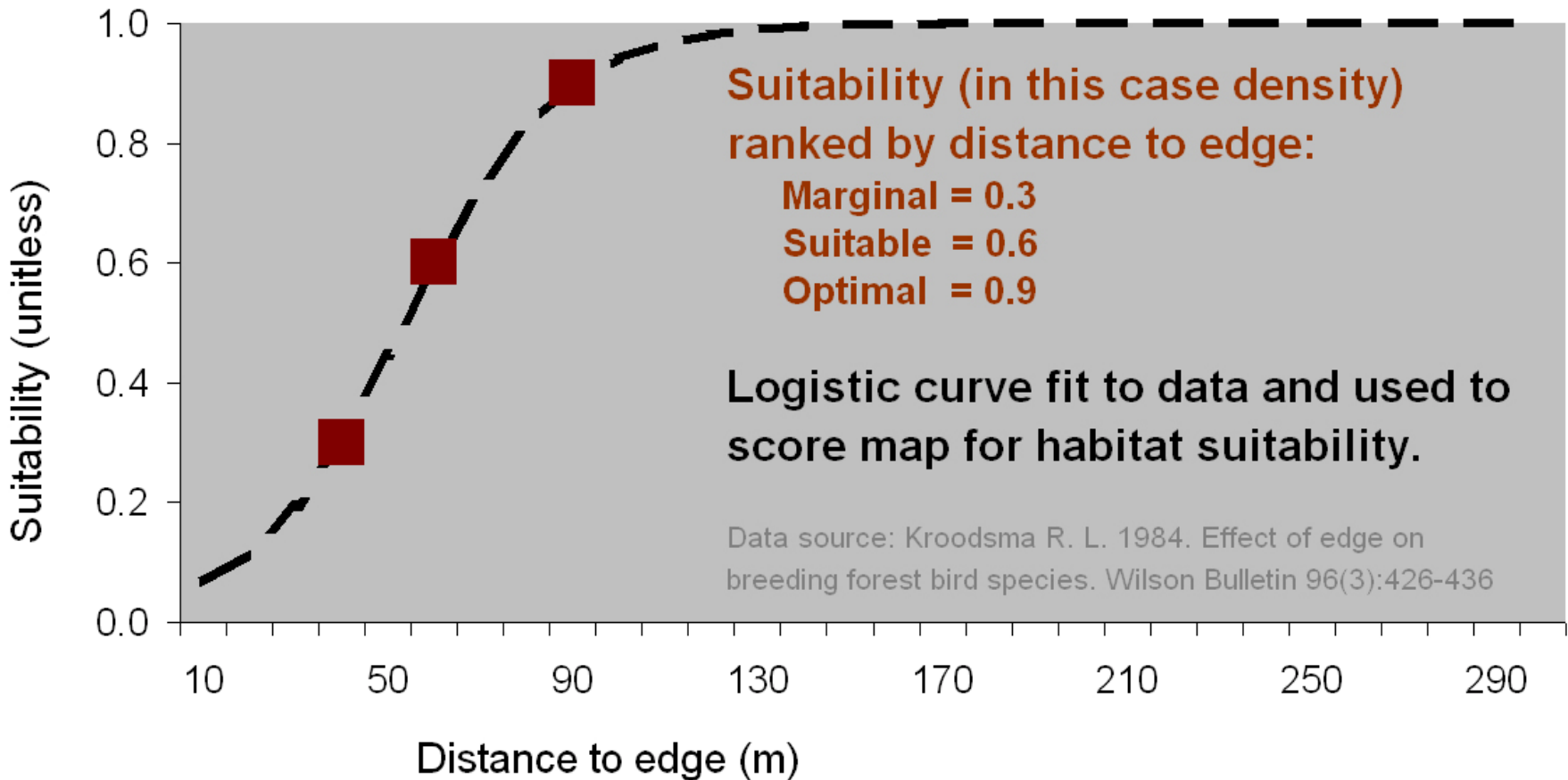
**b** affects slope of the “S”. Larger numbers shrink the curve.

**c** also affects slope of the “S” but less so. Larger numbers stretch the curve.



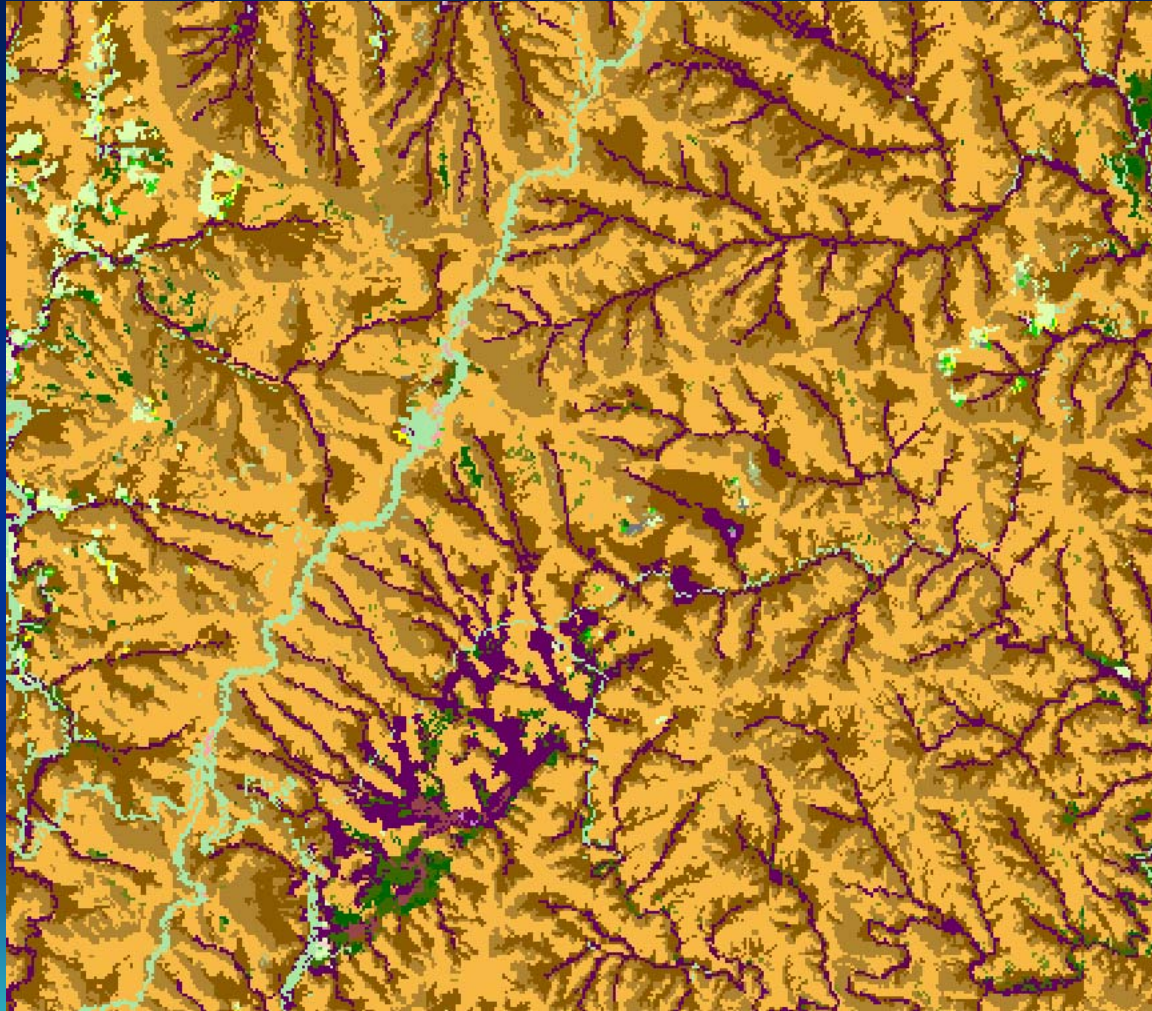
# Mapping Suitability Relationships

## Acadian Flycatcher





# Habitat Suitability Prediction

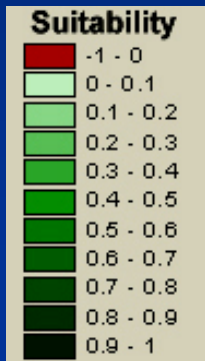


6 km

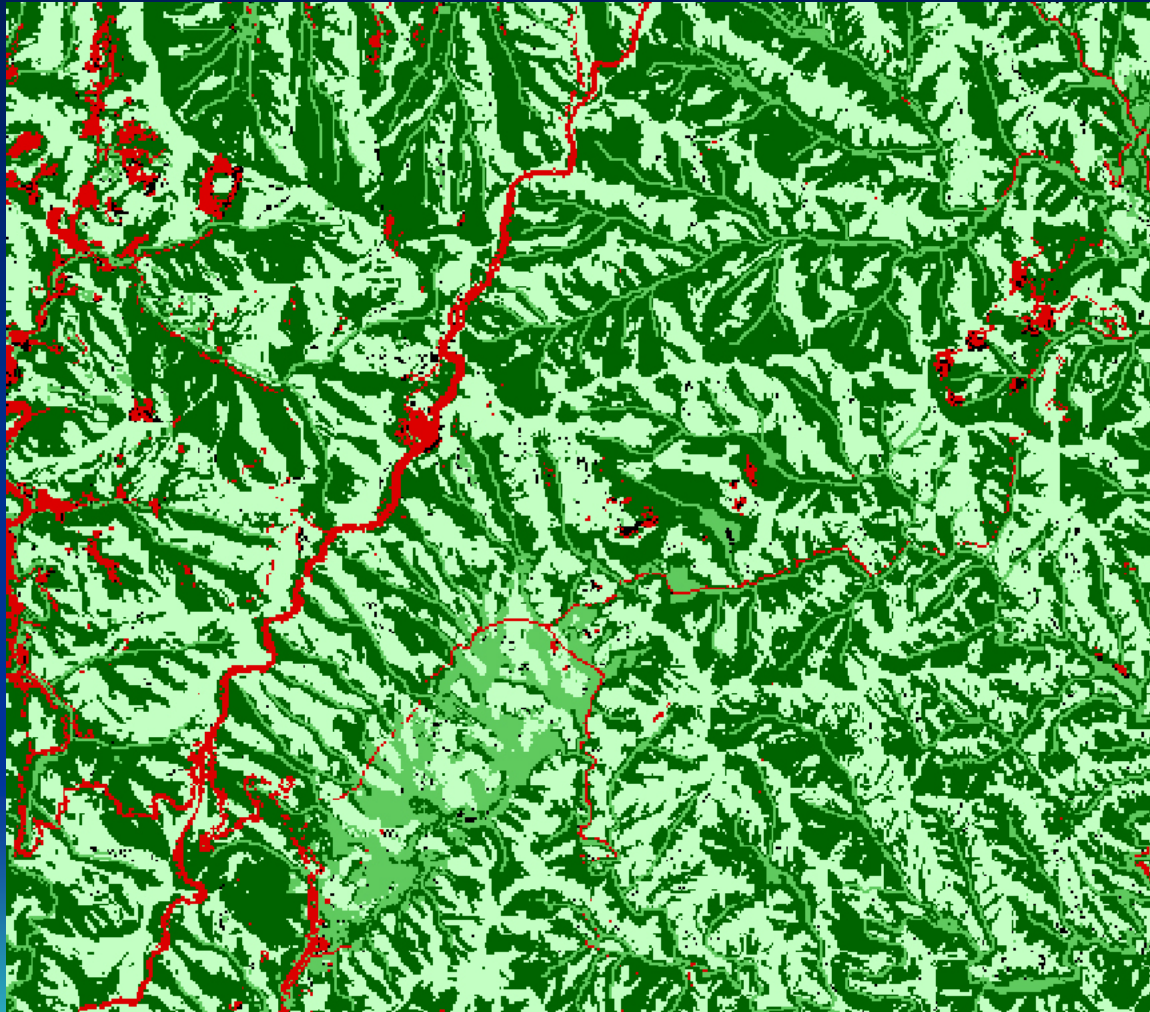
Input  
Avicentric  
land cover

# Lump Classes of Similar Suitability

Acadian  
Flycatcher



↔  
6 km

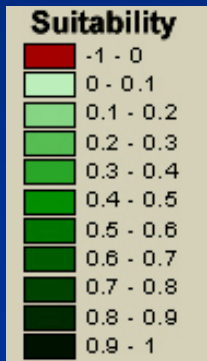


Input

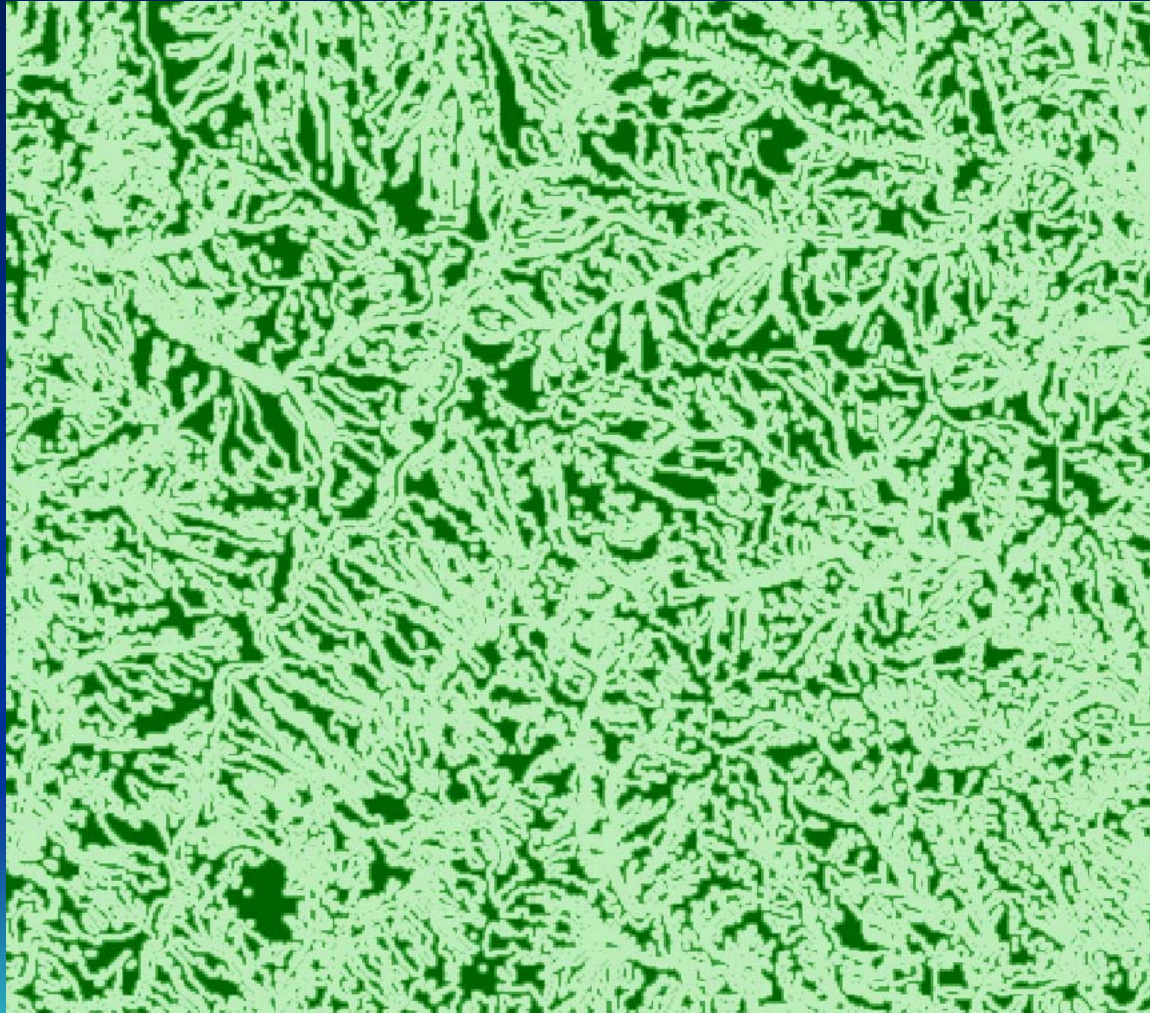
Flycatcher-  
centric land  
cover

# Calculate and Weight Distance to Edge

Acadian  
Flycatcher



↔  
6 km



Input  
Distance to  
Edge

# Map Algebra 2: Combine Maps

- **Suitability** ranked from 0 to 1:
  - Suitability under all conditions = Map1 \* Map2 \* Map3
- **Abundance/Density** Modeling
  - Extrapolate research results from sample locations (e.g., Logistic Regression)
- **Population** modeling
  - Combine maps of vital population rates that vary under different spatial conditions:

$$\begin{aligned}dR/dt &= a * R - b * R * F \\dF/dt &= e * b * R * F - c * F\end{aligned}$$

– Where:

- R are the number of prey
- F are the number of predators

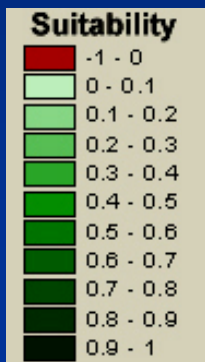
– and the parameters are defined by:

- a is the natural growth rate of prey in the absence of predation,
- c is the natural death rate of predators in the absence of prey,
- b is the death rate per encounter of prey due to predation,
- e is the efficiency of turning preyed prey into predators.

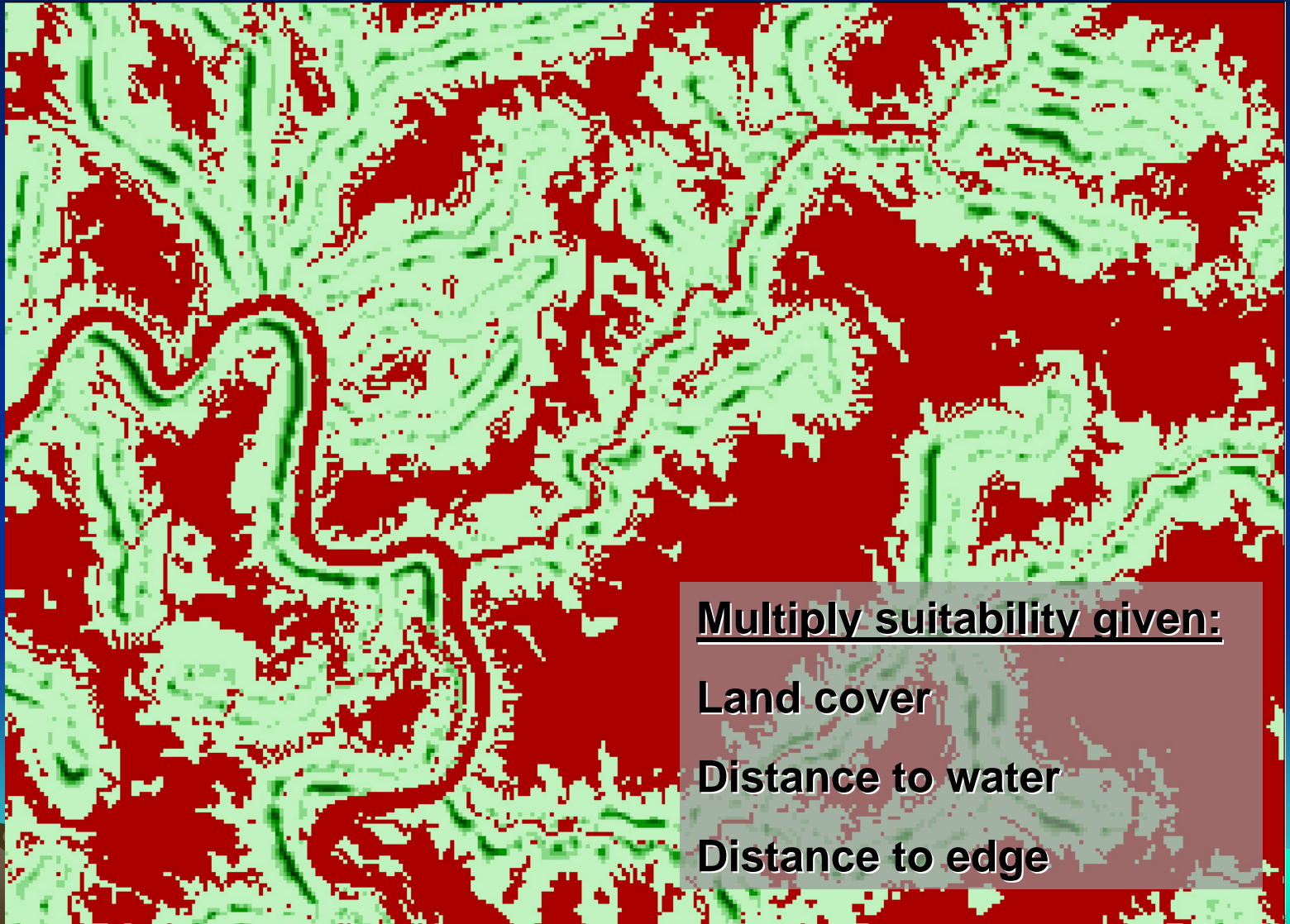


# Habitat Suitability Prediction

Acadian  
Flycatcher



↔  
1 km



# Explicitly State Assumptions!

- Allows testing to validate and refine predictions
- Example assumptions
  - Land cover, distance to water and distance to edge are all equally important considerations for mapping habitat suitability
  - Density, nesting success and predation rates are all equally relevant indications of habitat suitability
  - Relationships between patch/landscape/neighbor descriptions and habitat suitability are similar everywhere.

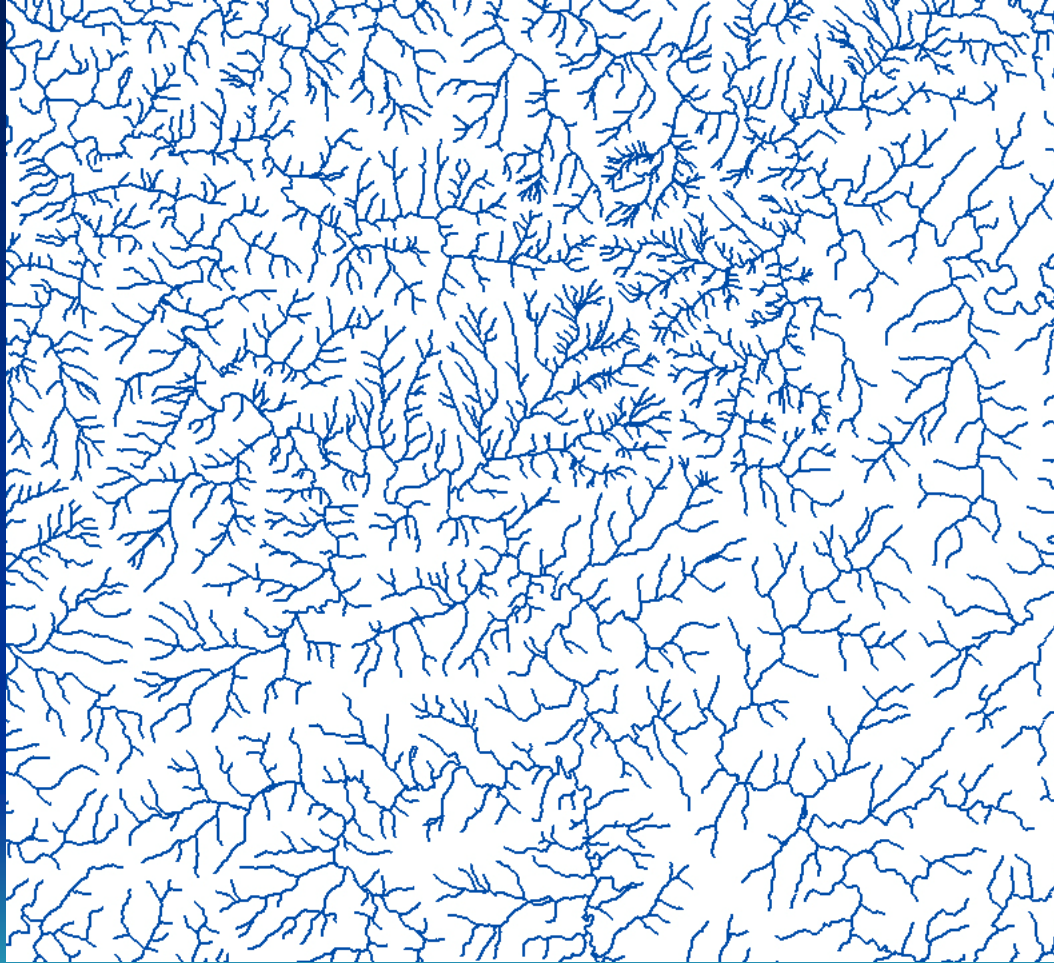


# Some Sources of Error

- Age of data
- Precision and availability of information
- Positional accuracy
- Classification appropriateness and accuracy
- Inconsistencies during data creation
  - Different interpreters or methods
  - Different classification schemes
  - Different scales of precision



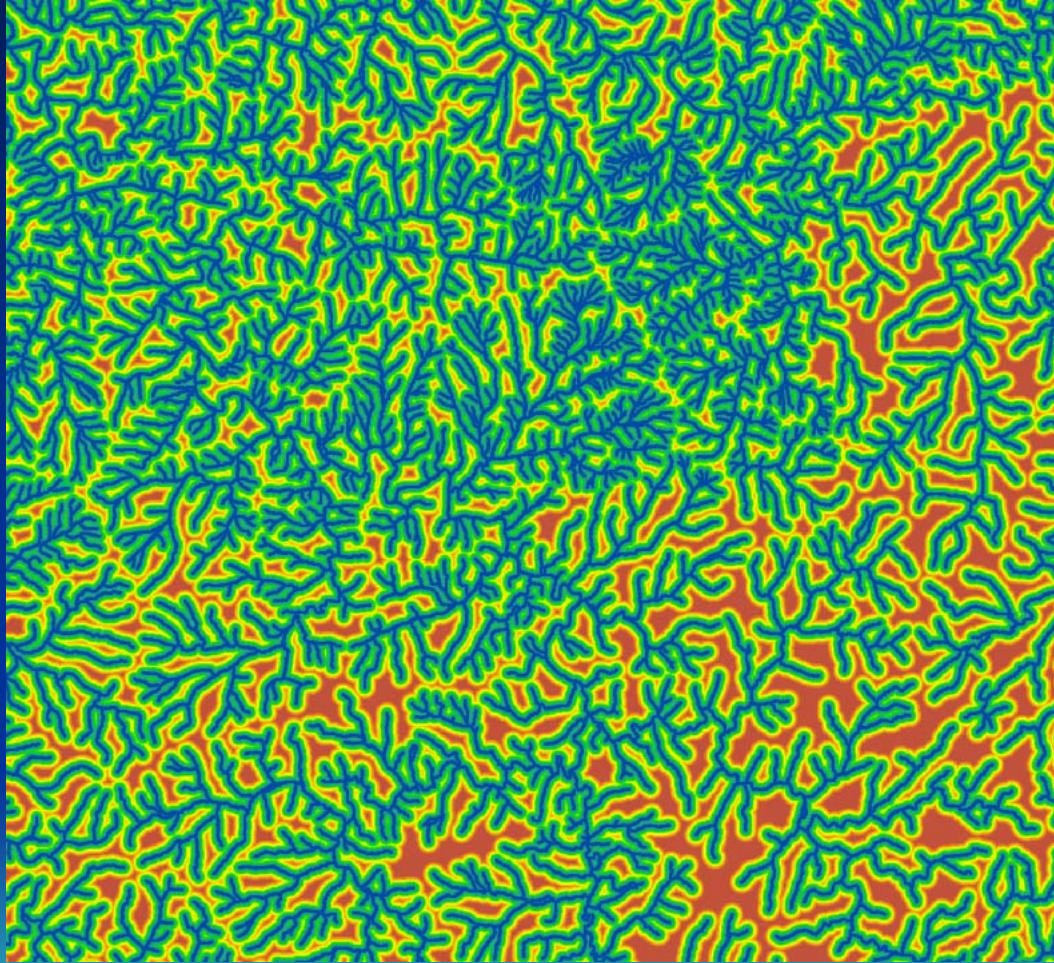
# Example: Digital Line Graphs



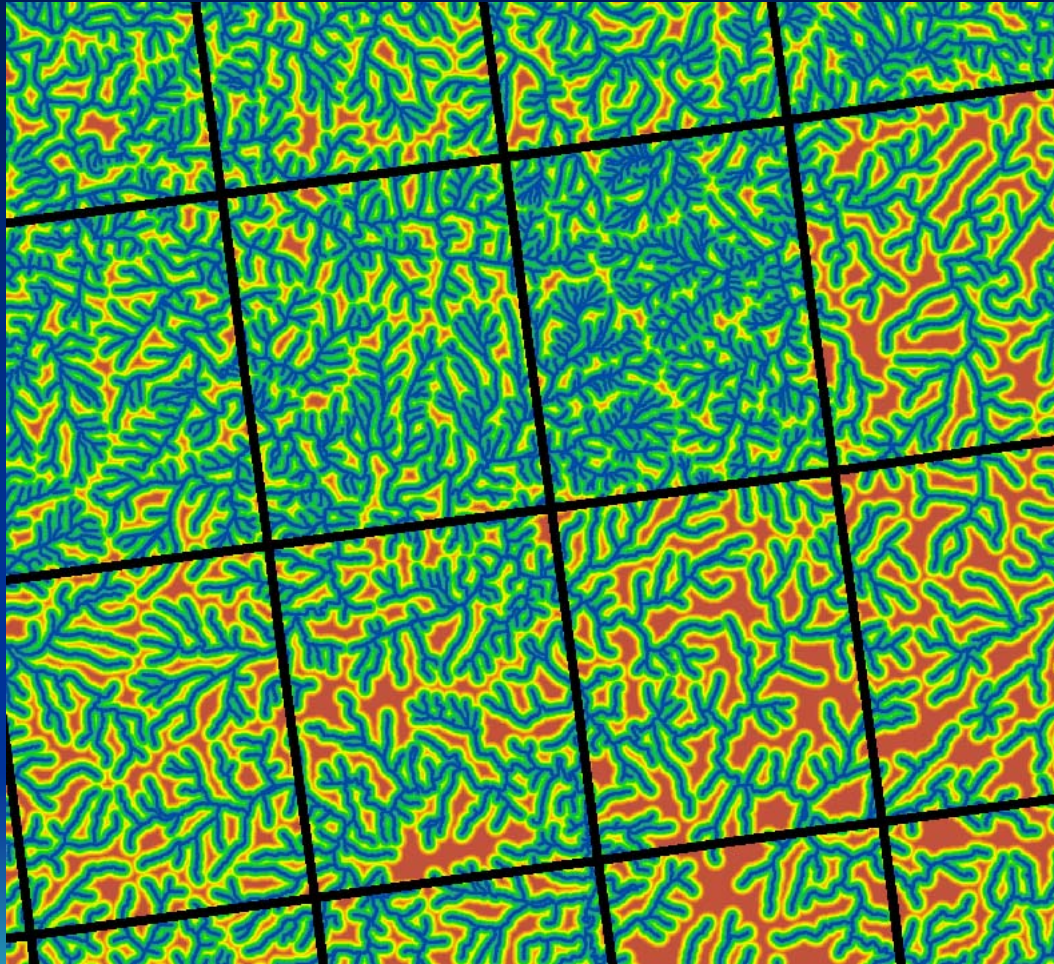
Used in the  
National  
Hydrographic  
Dataset



# Distance to Water



# Different Scales of Precision



# www.basic.ncsu.edu/segap

Southeast Gap Analysis Project - Mozilla

File Edit View Go Bookmarks Tools Window Help

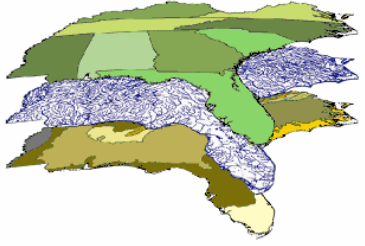
Back Forward Reload Stop <http://www.basic.ncsu.edu/segap/> Search Print

Home Bookmarks Google NCSU NC Gap Analysis Proj... WRAL.com - Home All About Birds NC Gap Analysis Proj... Wake County Emerg... NCSU - Login

## Southeast Gap Analysis Project

- Home
- Mission
- Land Cover
- Mapping
- Vertebrate
- Modeling
- Stewardship
- Analysis
- Contact
- Links


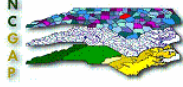


# SOUTHEAST GAP ANALYSIS PROJECT



The Southeast Gap Analysis Project (SEGAP) is a regional representative of the National Gap Analysis Program sponsored by the Biological Resources Division of the United States Geological Survey (USGS-BRD).

"The intent of the Gap Analysis is to provide focus and direction for proactive rather than reactive land management activities at the community and landscape levels" (J.Michael Scott, 1995).

A cooperative project by:



For questions or comments related to this website, please contact: [Steve\\_Williams@ncsu.edu](mailto:Steve_Williams@ncsu.edu)  
Updated 04-12-2004 by Andrew Bailey