Duke
NICHOLAS SCHOOL OF THE
ENVIRONMENT

ENVIRONM 761

Landscape Assessment - Part 1: Habitat patch geometry

ENVIRON 761

Geospatial Applications for Conservation & Land Management

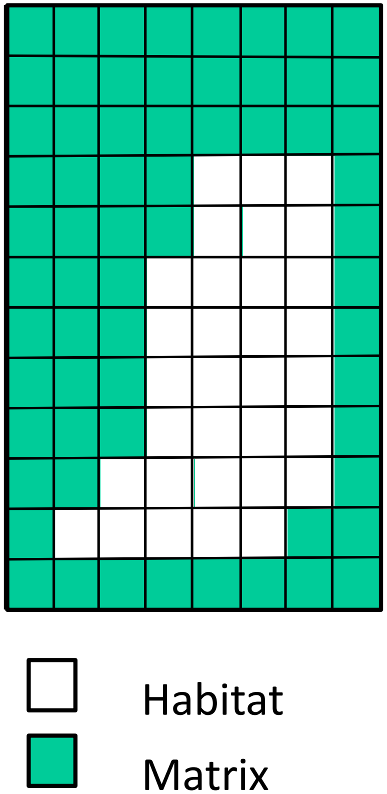
Central question

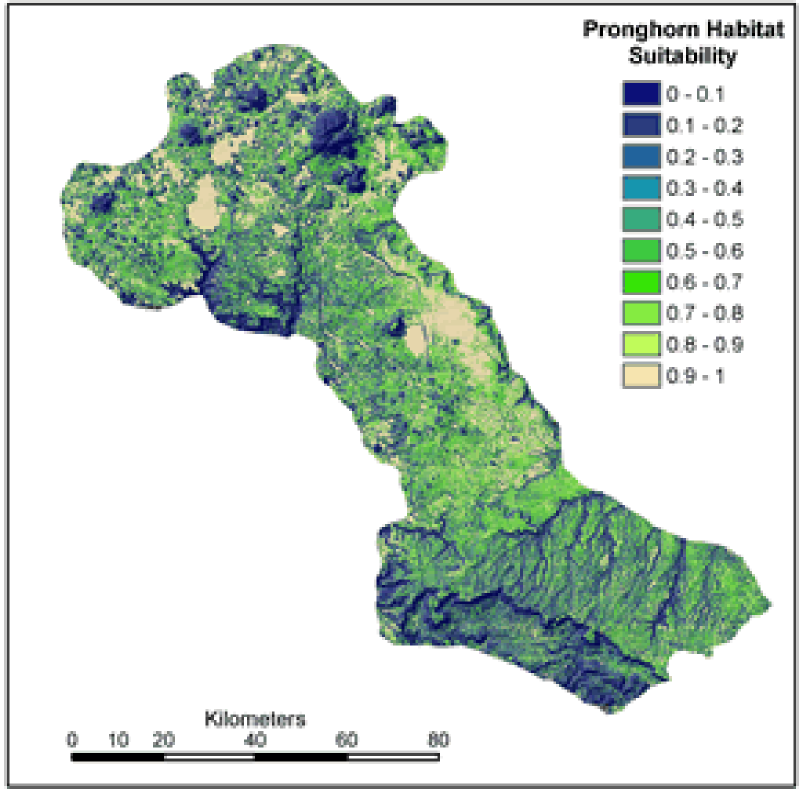
If we can't feasibly protect all the habitat for a given species, what characteristics of "habitat" might lead us to favor protecting some habitat areas over others?

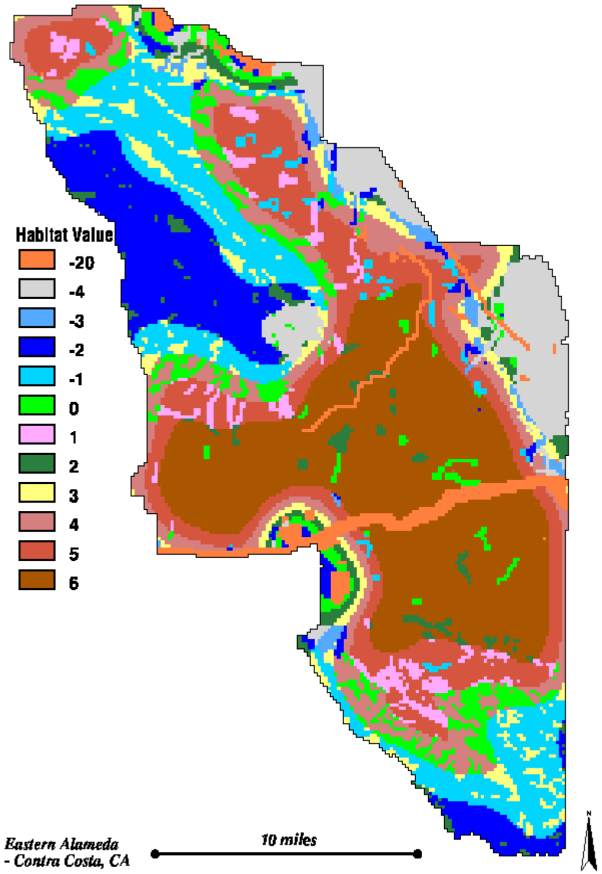
Habitat requirements

Species	Definition of core habitat	Citation
Mountain Quail 	· A contiguous area of habitat of medium to high quality that has an area greater than two home ranges in size · In continuous use by the species successful enough to produce offspring that disperses	Timossi, et al. (1995)
Marten 	· 30 to 50 square km, 75% of which is in suitable stands (overstory of at least 40% cedar, spruce, pine that has a canopy closure > 75%)	Watt, et al. (1996)
Coachella Lizard 	· Shall contain populations of sufficient size to be considered viable independent of others · Core cannot be fragmented by roads or development · Core has intact processes including sand source and delivery system for the lizard · Each contains a sand source	
Prairie Chicken 	core habitat as patches of suitable habitat (mixed grass prairie, sandhill prairie, tallgrass prairie, sand sagebrush or shinnery) that are: · either more than 2,000ha in area or between 500ha to 2,000ha in area and no more than · 10km from another patch of at least 500ha in size	Hagen et al. 2004 and

Starting Point: *Suitable Habitat*







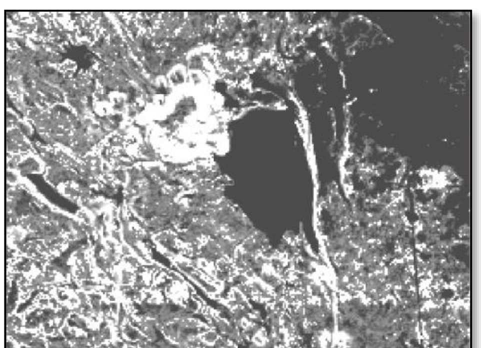
Step 1: Habitat → Habitat *Patches*

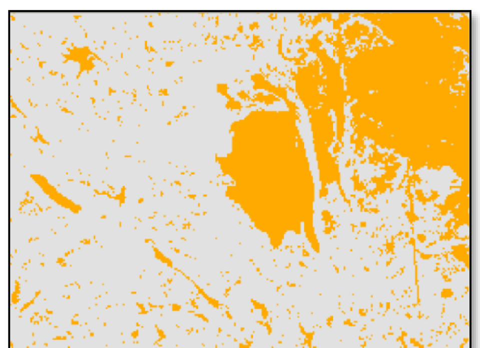
Pronghorn distribution model → Pronghorn habitat map → Pronghorn habitat-patch map

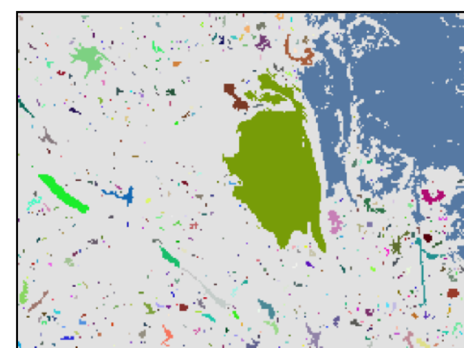
<u>Continuous</u>:
Pronghorn habitat suitability (0.0-1.0)

<u>Binary</u>:
Separates pixels into suitable and non-suitable classes

<u>Nominal</u>:
Clusters of connected habitat cells are grouped and given a unique ID

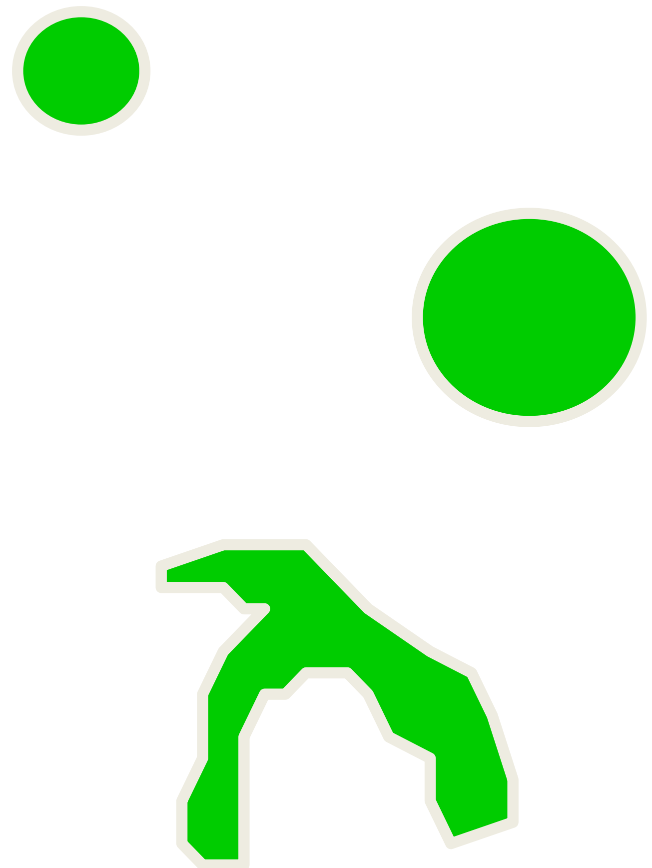


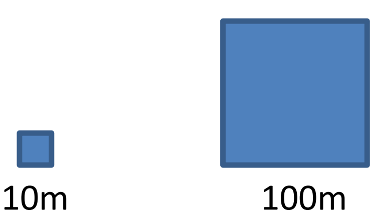




Habitat patch *geometry*

- Area
- Perimeter or ‘edge’
- Edge to area ratio





Shape complexity

Shape complexity can be summarized in terms of a simple edge/area ratio. Most patch definition procedures provide for such indices simply, even automatically. Vector GIS packages keep track of the area and perimeter (edge) of each patch (polygon) in a vector coverage. More frequently, edge/area ratios are normalized for easier interpretation. For example,

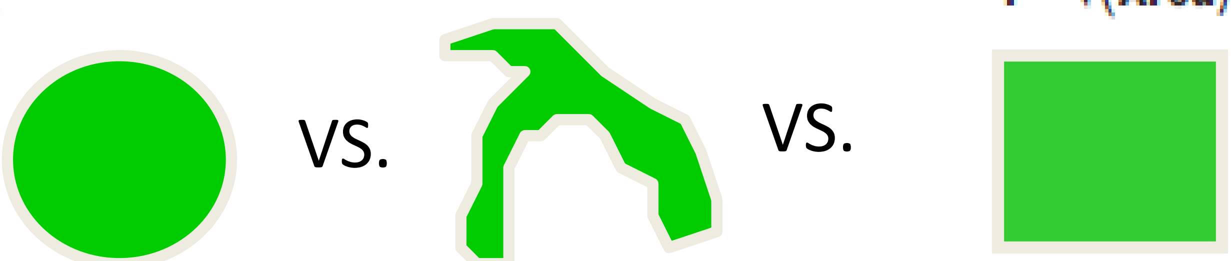
$$\text{Shape Index} = \frac{\text{Perimeter, m}}{\text{Perimeter of most simple shape, m}}$$

compares the edge/area ratio to the expectation for a circle. A similar normalization can be applied to compare raster shapes to a square.

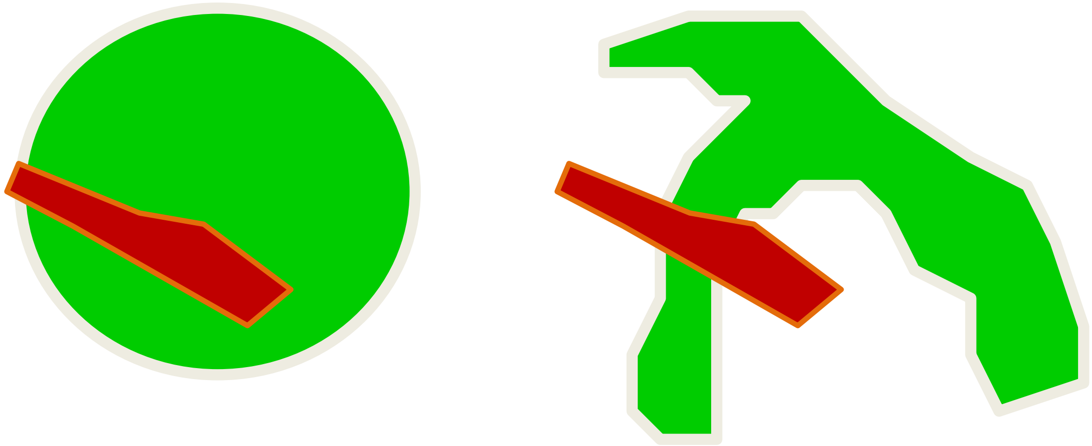
$$E / (2\sqrt{\pi A})$$

E = perimeter

$$\frac{\text{Perimeter}}{4 * \sqrt{(\text{Area})}}$$

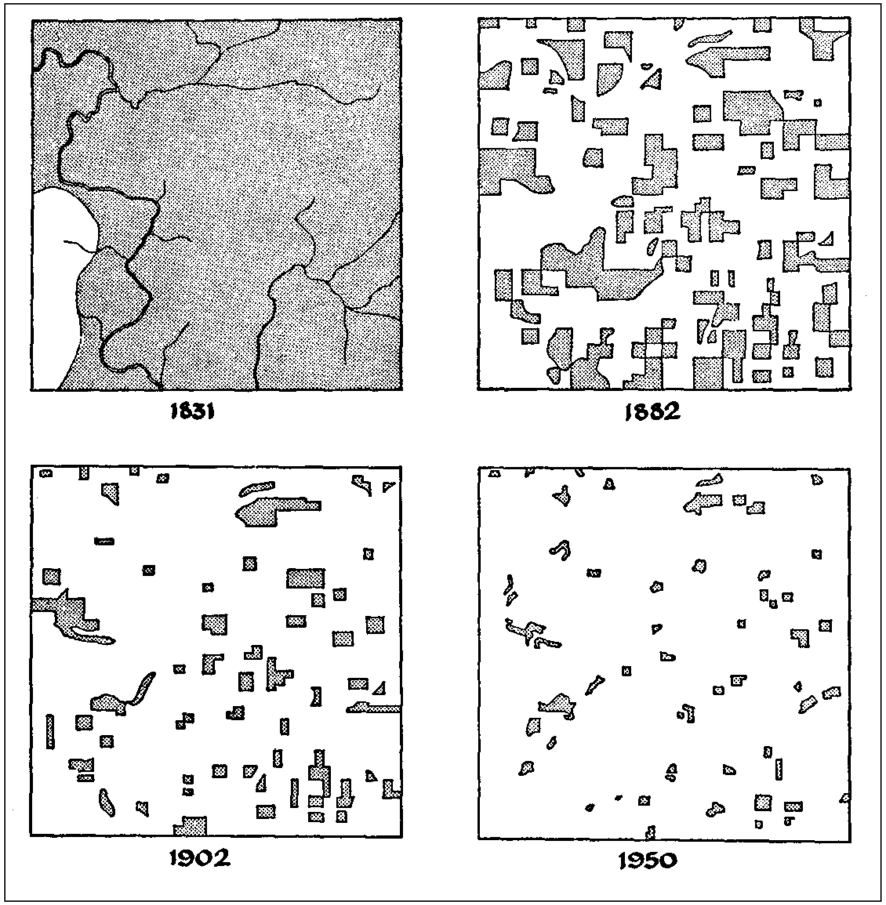


Shape complexity & fragmentation



More complex shapes are more likely to split into fragments…

Fragmentation: Conservation implications



- **Landscape effects**
  - Loss of habitat
  - Increased isolation of remaining habitat
  - Effects on large scale natural processes (fire, seed dispersal, hydrology)
- **Community effects**
  - Increased exposure to predation, parasites, pathogens, invasive species (edge effects)
- **Population effects**
  - Metapopulations, reproductive isolation, local extirpations

Impacts of fragmentation

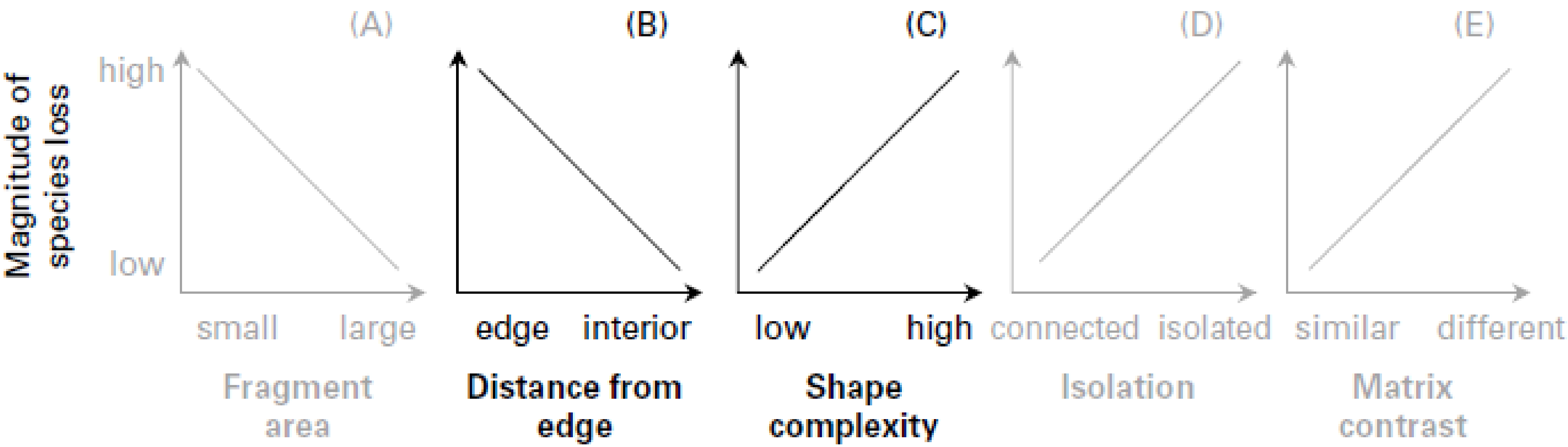
- ***Physical (edge effects)*** ← Today
  - Alteration of the micro-climate within and surrounding the landscape remnant

- ***Biogeographic***
  - Isolation of the remnant from other remnant patches

Effects of fragmentation

Confounding factors in the detection of species responses to habitat fragmentation

Robert M. Ewers[1,2,3]* and Raphael K. Didham[1]

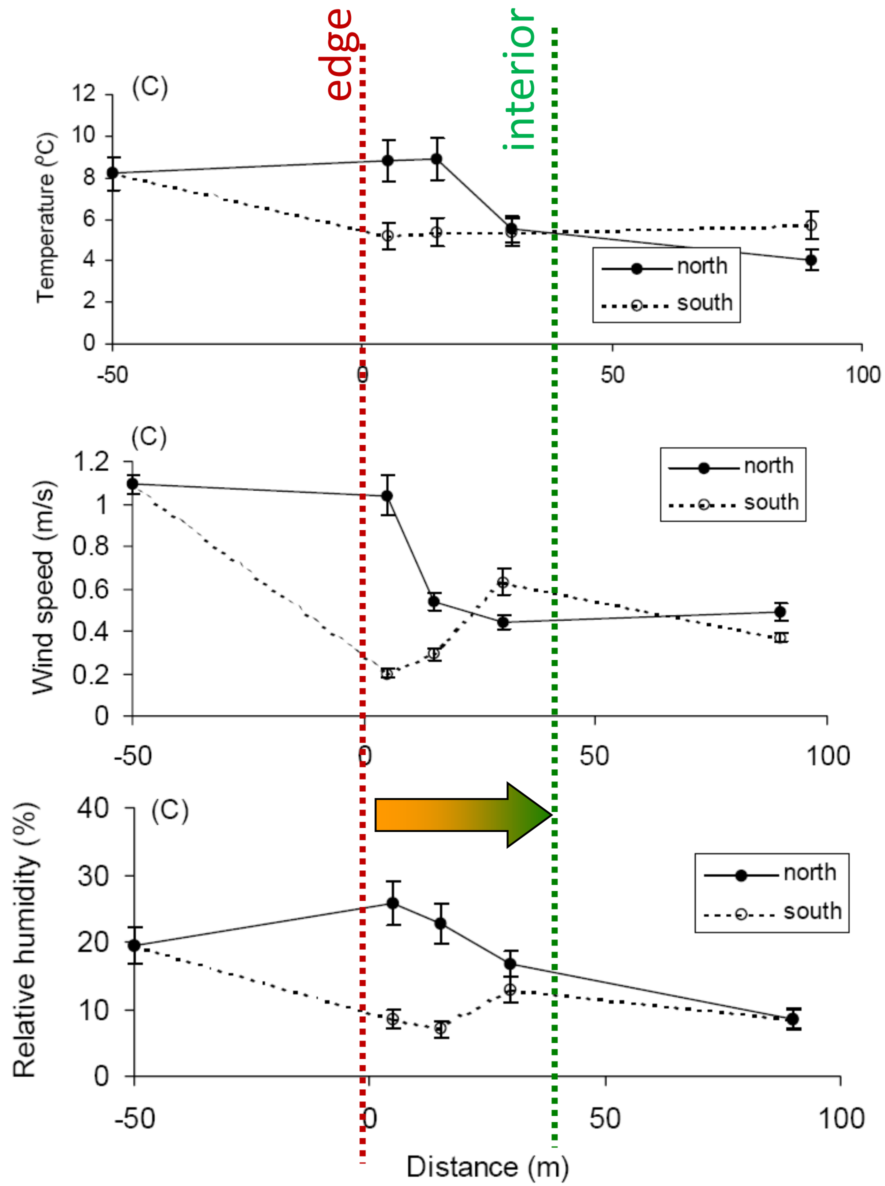


Physical impacts of fragmentation

- Radiation Flux
- Wind
- Water flux

Physical impacts of fragmentation

Example:
Direct measurements of abiotic (microclimate) edge effects.



Edge effects in a lowland temperate New Zealand rainforest

DOC SCIENCE INTERNAL SERIES 27

David A. Norton

Physical impacts of fragmentation

***Radiation Flux* – Potential Consequences**

- Increased radiation gradient change at the edge.
- Latitude influences the radiation effects.
- Air temperature increased at edges.

Physical impacts of fragmentation

Wind **– Potential Consequences**

- Increased wind-throw or wind pruning in trees.
- Wind sheer may affect bird breeding success.
- Lower regeneration success for existing plant species.
- Increased transfer of external seed sources

Physical impacts of fragmentation

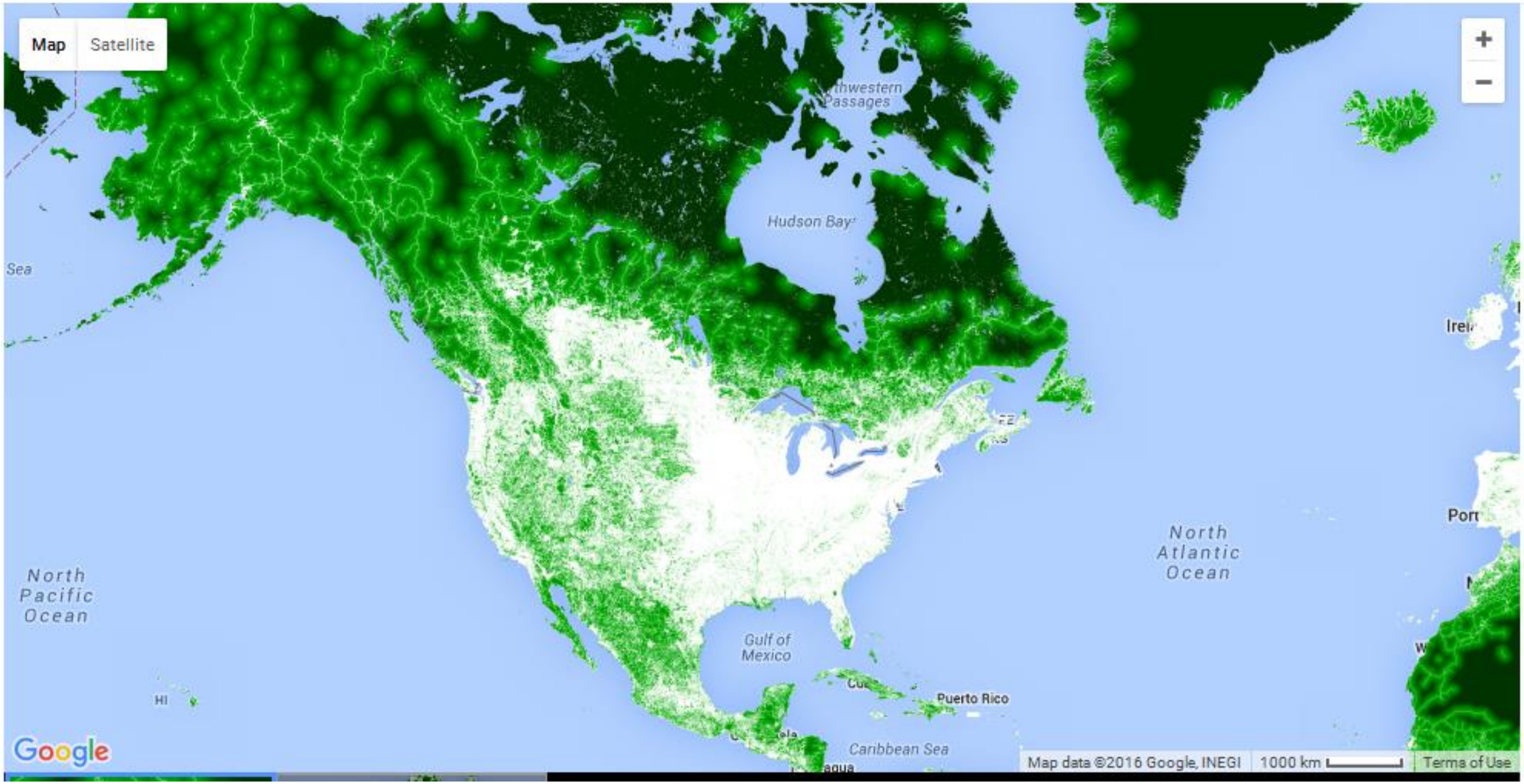
Water flux – Potential Consequences

- Altered rates of rainfall interception and evapotranspiration.
- Changes in surface & ground water flows.
- Decrease in buffering.
- Potential increase in erosion

- Potential salt intrusion from raised water tables.

Habitat *Cores*

Google Earth Engine: 1km from roads

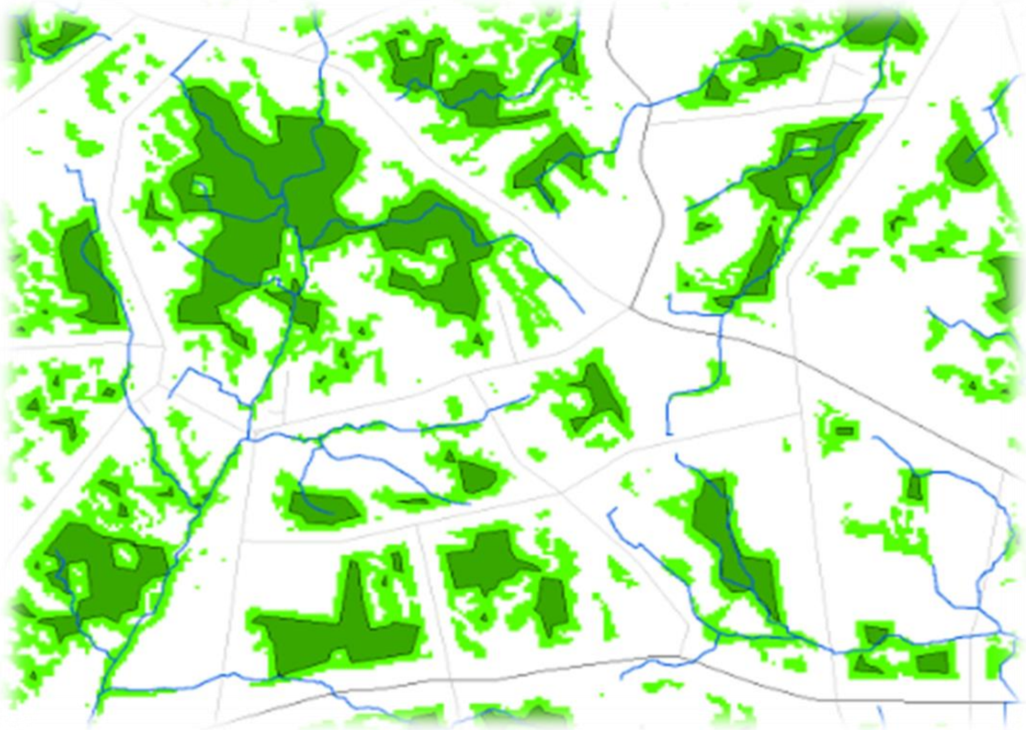


https://explorer.earthengine.google.com/#gallery/Roadless1km

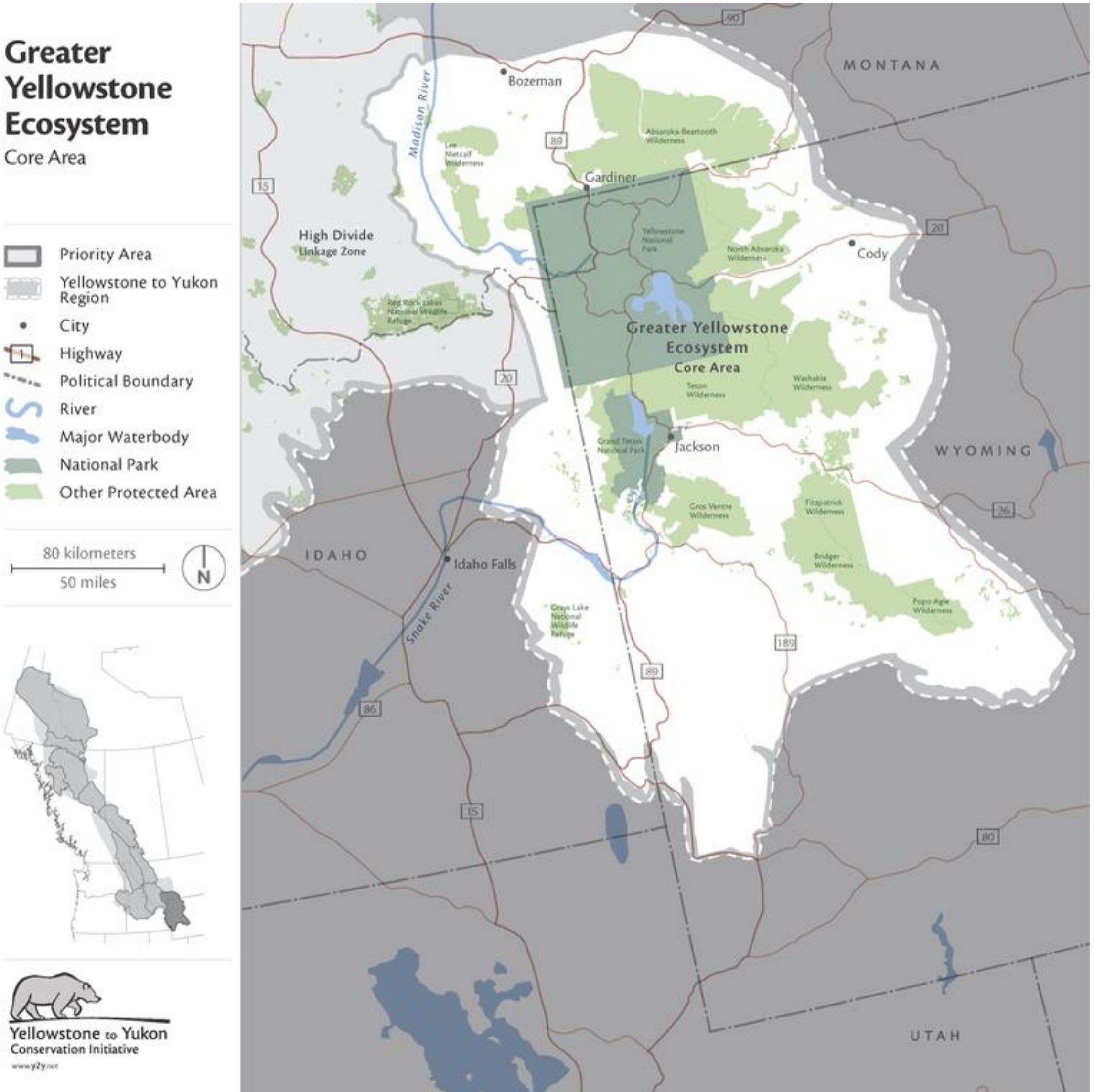
Habitat *Cores*

What are habitat "cores"?

- habitat area free of edge effects (Zipperer 1993)
- area of limited human access (Noss 1987, Soule & Terborgh 1999)



Habitat *Cores*



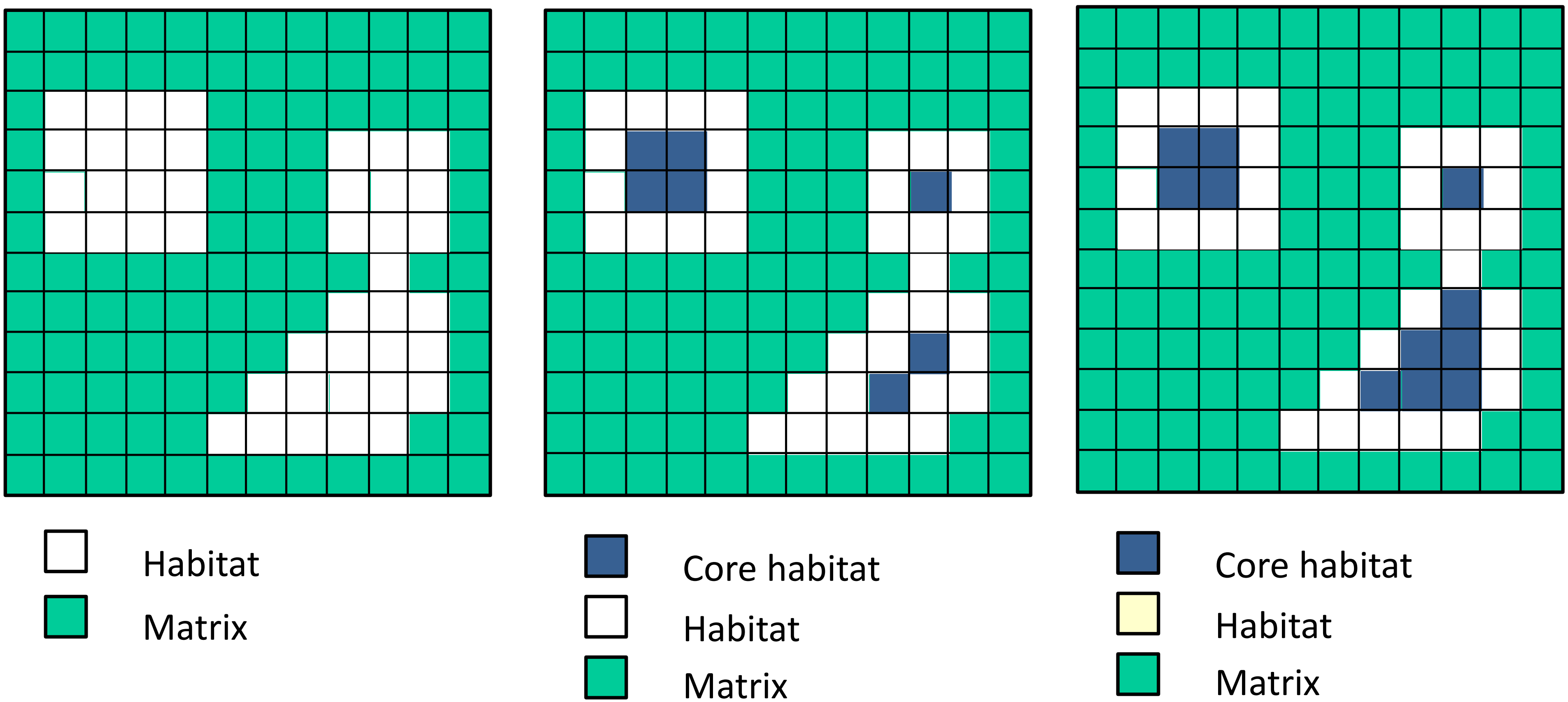
Core:

Area of "intact habitat" that is unaffected by human disturbance and other neighboring influences…

Scale dependent…

Mapping habitat cores

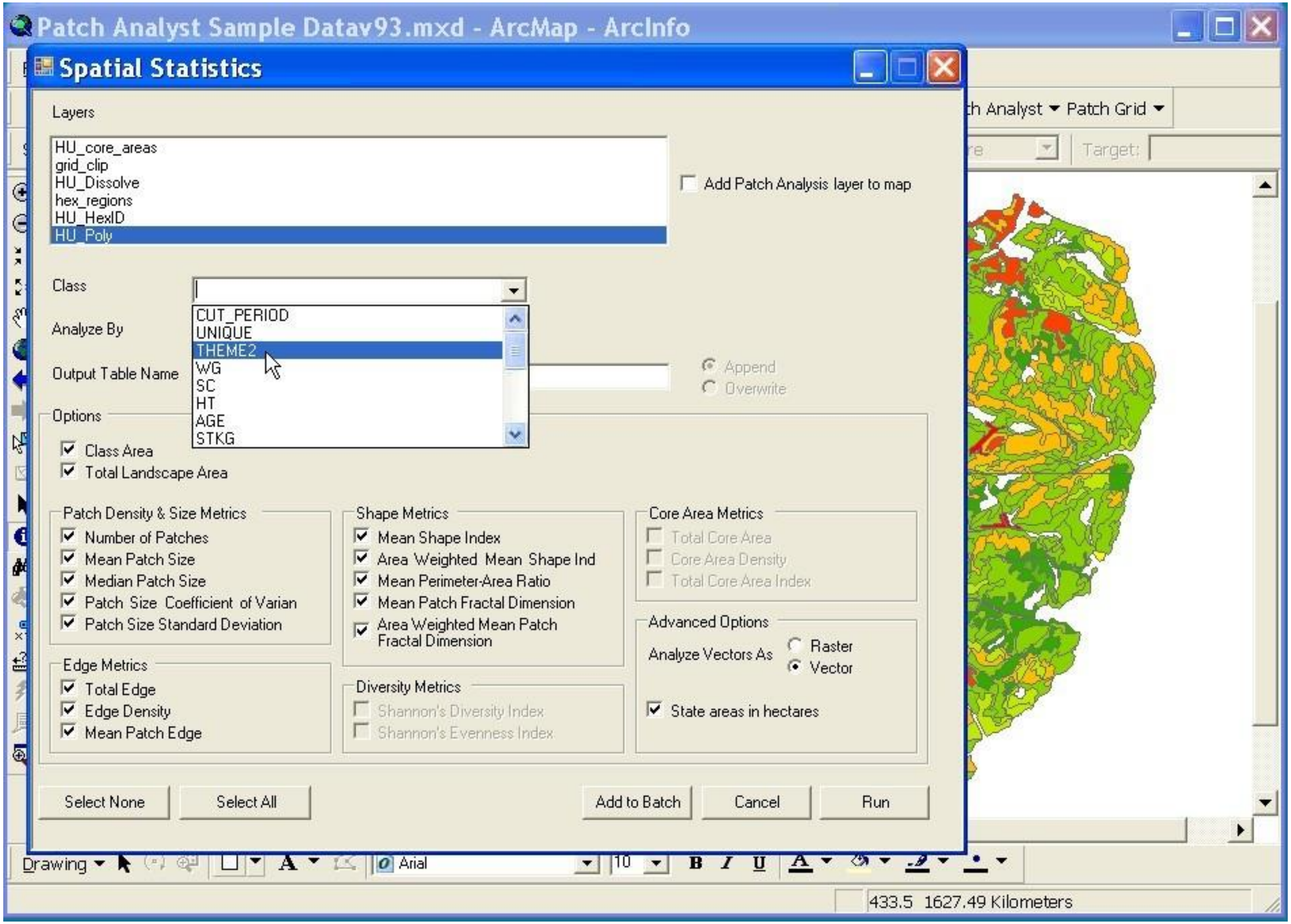
“Buffer-defined” core



Patch Analyst 5
Centre for Northern Forest Ecosystem Research

FRAGSTATS:

Patch Analyst



Patch Analyst

Installation of Patch Analyst for ArcGIS 10 [back]

Download Patch Analyst

Install Fix for ArcMap 10.3 (Failed to Register Dlls or Registration Failed)

Esri Registration Utility

Registration failed.
Could not load file or assembly 'ESRI.ArcGIS.ADF.Local, Version=10.2.0.0, Culture=neutral, PublicKeyToken=8fc3cc631e44ad86' or one of its dependencies. The system cannot find the file specified.

OK

http://www.cnfer.on.ca/SEP/patchanalyst/Patch5_2_Install.htm

FRAGSTATS

http://www.umass.edu/landeco/research/fragstats/fragstats.html

SDM Toolbox…

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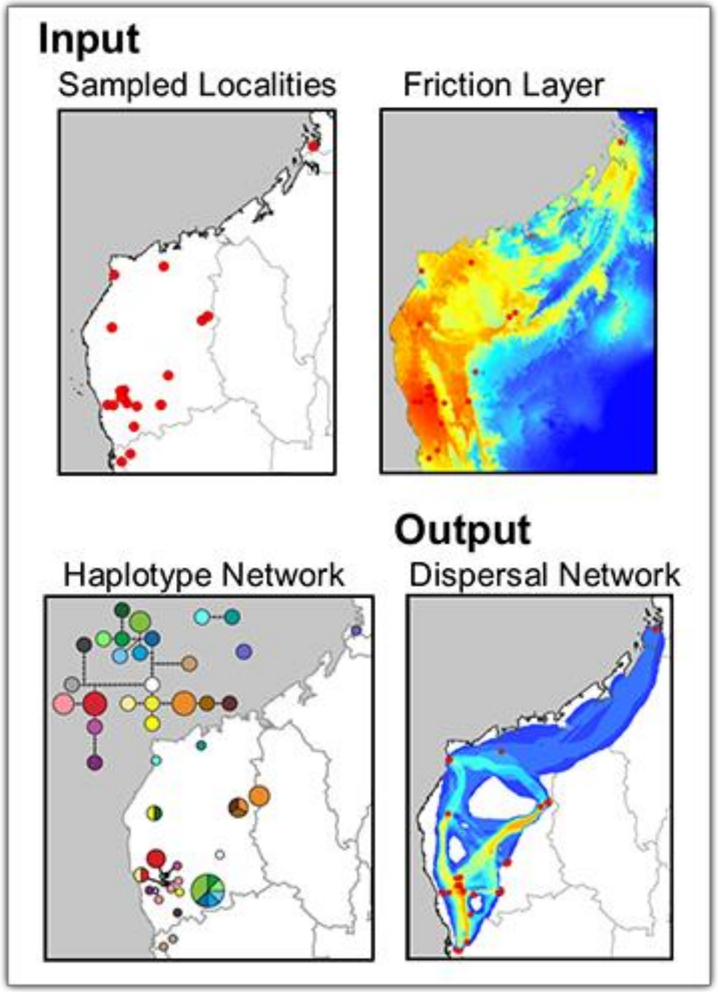
Home

March 13, 2015. Software update (v1.1c)- Please update your version of SDMtoolbox!
Please subscribe to email software update notifications

SDMtoolbox now has a forum!

SDMtoolbox is a python-based ArcGIS toolbox for spatial studies of ecology, evolution and genetics. SDMtoolbox consists of a series python scripts (71 and growing) designed to automate complicated ArcMap (ESRI) analyses. A large set of the tools were created to complement MaxEnt species distribution models (SDMs) or to improve the predictive performance of MaxEnt models (for an overview, see chapter 5 in the user guide Running a SDM in MaxEnt: from Start to Finish). MaxEnt uses maximum entropy to model species' geographic distributions using presence-only data (Phillips et al. 2006) and has become one of the most prevalent methods due to its high predictive performance, computational efficiency and ease of use. SDMtoolbox is not limited to analyses of MaxEnt models and many tools are also available for use on other data (*i.e.* haplotype networks) or the results of other SDM methods (see Universal SDM Analyses).

Software citation: Brown J.L. 2014. SDMtoolbox: a python-based GIS toolkit for landscape genetic, biogeographic, and species distribution model analyses. Methods in Ecology and Evolution DOI: 10.1111/2041-210X.12200



Mapping habitat cores

Density-defined core

Scenario: CA Spotted Owl

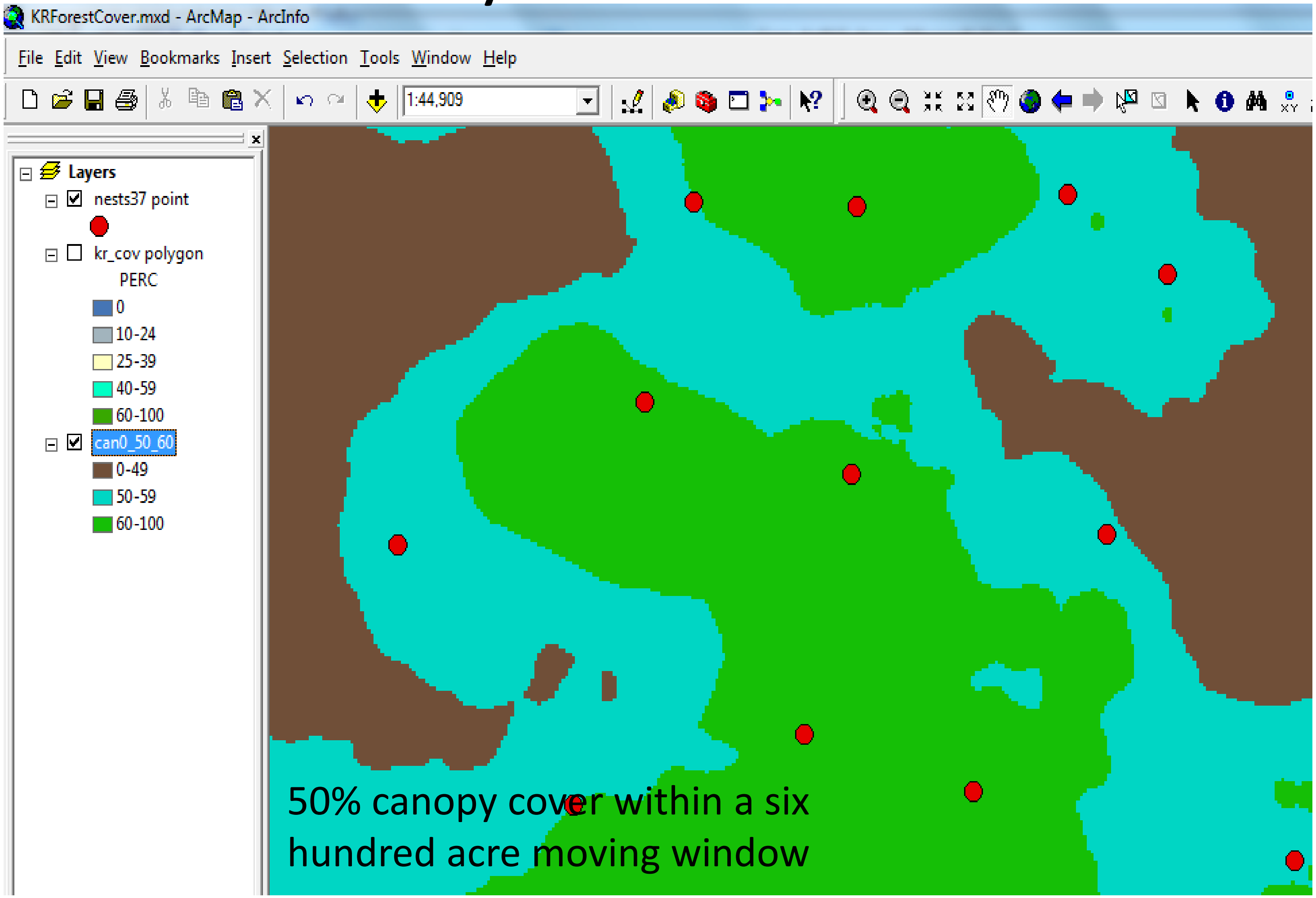
- Nests are in dense stands w/high canopy closure (>60%)
- But owls are often found in areas where there's ~600 acres of land with a ***preponderance*** of high canopy closure.

So… suitability of nest sites is not only a function of the stand in which the nest is found, but also a function of what surrounds the nest up to a circular region of 243 hectares (r = 880m).

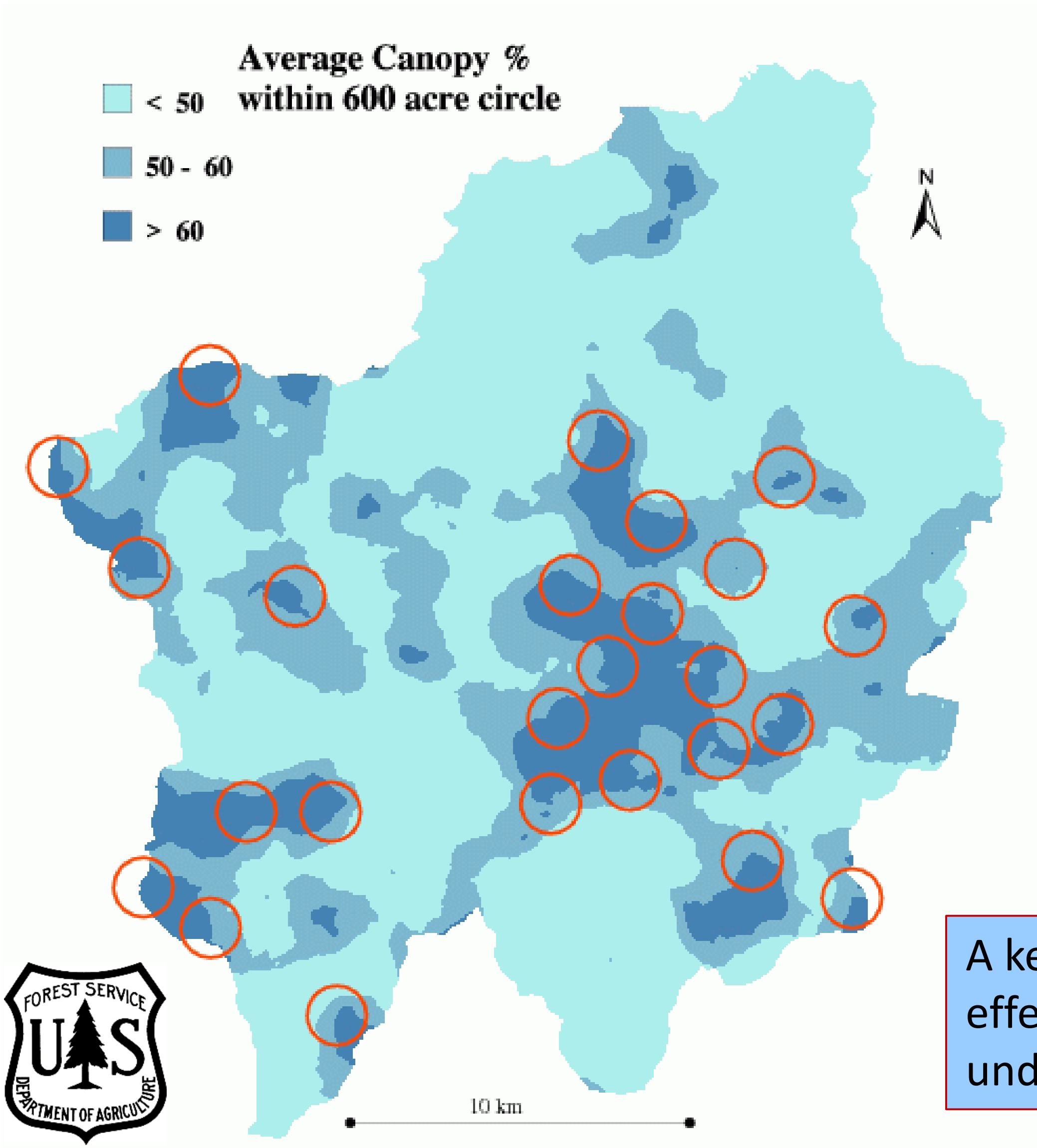
Gerrard, R.A. (2006) "Measuring Habitat Quality and Carrying Capacity for the California Spotted Owl Case Study using Data from Sierra National Forest," Interim Report Compiled for SNRC and Plumas-Lassen-Tahoe NFs.

Mapping habitat cores

Density-defined core



Mapping habitat cores



Within the Kings Canyon region of the Sierra National Forest, modeled "Core" spotted owl habitat is shown as light blue to dark blue(based upon density defined core)

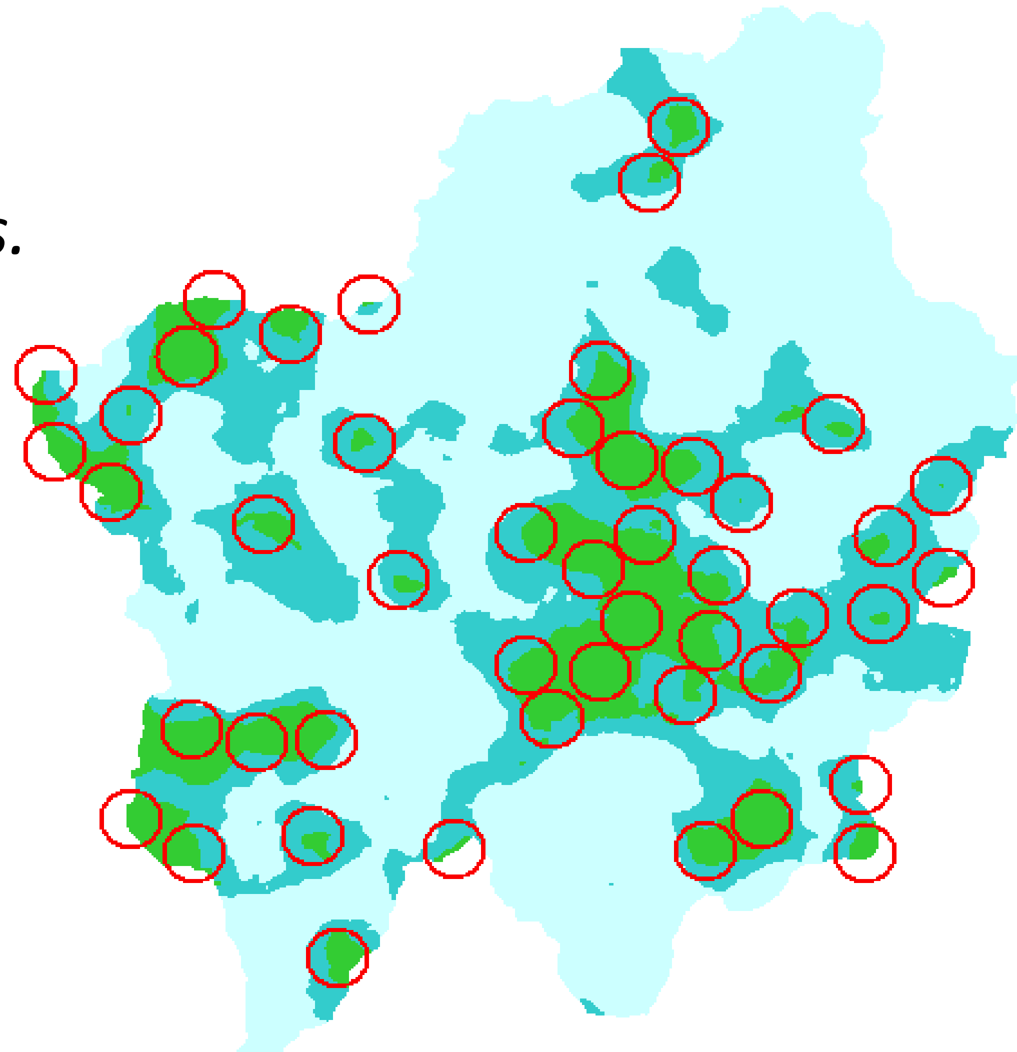
○ Actual nest site

A key question: what can this support, how effective can this core be due to its undulating nature?

Modeling “*effective*” core

= area large enough to support a territorial species.

How many can you fit within the configuration of habitat within a landscape without overlapping?



Modeling "effective" core

"ScatterMax" algorithm

Method: Random Maximum Scatter (assume a raster)

Step 1: From the core habitat, identify those raster cells which can serve as territorial centers. Define this as Ω list , set $k=0$, set $F=$ null and go to step 2.

Step 2: Select from random a cell j from list . Ω Place cell j on list F, increment k by 1, and proceed to step 3.

Step 3: Remove from list Ω all cells that are less than $2*R$ distance away from cell j and then proceed to step 4

Step 4: If Ω list is empty, stop with set F containing k centers whose territories do not overlap. Otherwise return to step 2.

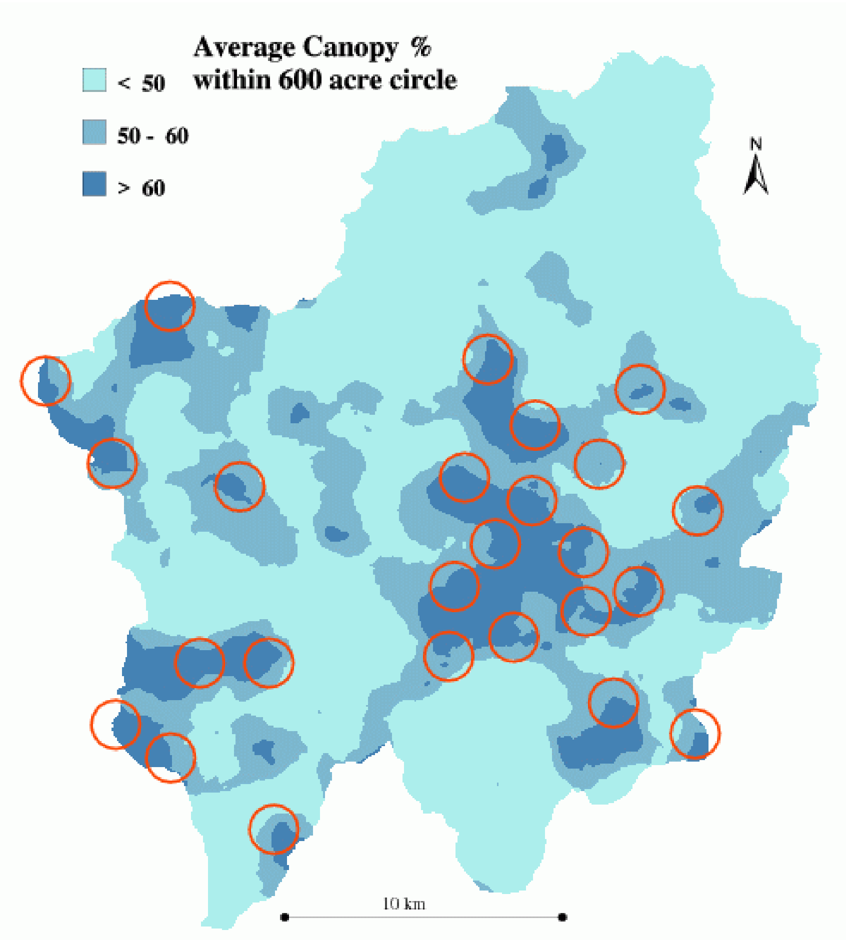
Modeling "effective" core

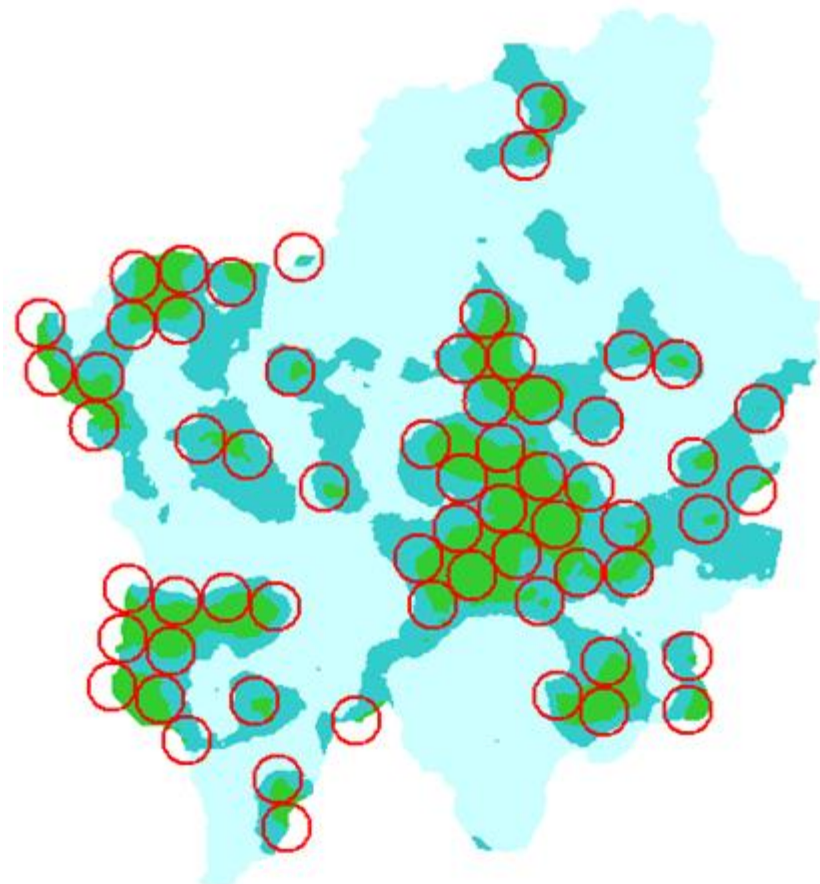
- Maximum Packing heuristic/r-separation

Method: RSLM heuristic

Step 1:	From the core habitat, identify those raster cells which can serve as territorial centers. Define this as Ω list , set $k=0$, set $F=$null and go to step 2.
Step 2:	Select from random a cell j from list Ω. Place cell j on list F and increment k by 1 and proceed to step 3.
Step 3:	Remove from list Ω all cells that are less than 2^*R distance away from cell j and then proceed to step 4.
Step 4:	If k<4, find the cell in Ω that minimizes the combined distances to the first k sites already in F. Make this the site of set F, increment k to $k+1$ and return to step 3. If $k \geq 4$ then go to step 5.
Step 5:	If list Ω is empty, stop with set F containing k centers whose territories do not overlap. otherwise proceed to step 6
Step 6:	Find a cell in Ω that minimizes the combined distances to the first 4 sites selected in set F. Make this the site of set F, increment k to $k+1$ and then proceed to step 7.
Step 7:	Remove from list Ω all cells that are less than 2^*R distance away from cell j and then return to step 5.

Maximum habitat packing

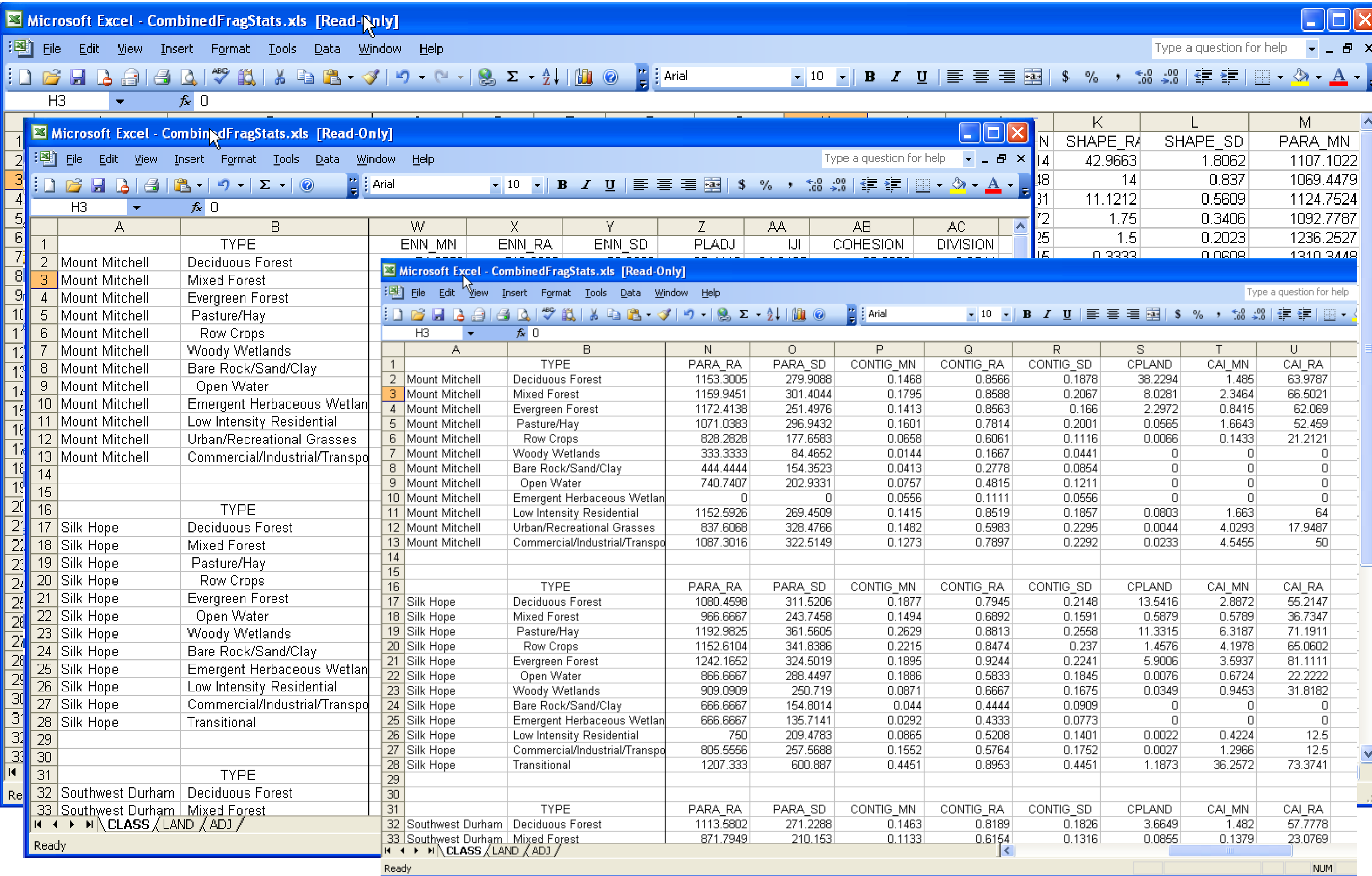




FRAGSTATS OUTPUTs

Patch Metrics	
P7	Perimeter-Area Ratio (PARA)
P8	Shape Index (SHAPE)
P9	Fractal Dimension Index (FRAC)
P10	Linearity Index (LINEAR)
P11	Related Circumscribing Circle (CIRCLE)
P12	Contiguity Index (CONTIG)
Class Metrics	
C23	Perimeter-Area Fractal Dimension (PAFRAC)
C24-C29	Perimeter-Area Ratio Distribution (PARA_MN, _AM, _MD, _RA, _SD, _CV)
C30-C35	Shape Index Distribution (SHAPE_MN, _AM, _MD, _RA, _SD, _CV)
C36-C41	Fractal Index Distribution (FRAC_MN, _AM, _MD, _RA, _SD, _CV)
C42-C47	Linearity Index Distribution (LINEAR_MN, _AM, _MD, _RA, _SD, _CV)
C48-C53	Related Circumscribing Circle Distribution (CIRCLE_MN, _AM, _MD, _RA, _SD, _CV)
C54-C59	Contiguity Index Distribution (CONTIG_MN, _AM, _MD, _RA, _SD, _CV)
Landscape Metrics	
L23	Perimeter-Area Fractal Dimension (PAFRAC)
L24-L29	Perimeter-Area Ratio Distribution (PARA_MN, _AM, _MD, _RA, _SD, _CV)
L30-L35	Shape Index Distribution (SHAPE_MN, _AM, _MD, _RA, _SD, _CV)
L36-L41	Fractal Index Distribution (FRAC_MN, _AM, _MD, _RA, _SD, _CV)
L42-L47	Linearity Index Distribution (LINEAR_MN, _AM, _MD, _RA, _SD, _CV)
L48-L53	Related Circumscribing Circle Distribution (CIRCLE_MN, _AM, _MD, _RA, _SD, _CV)
L54-L59	Contiguity Index Distribution (CONTIG_MN, _AM, _MD, _RA, _SD, _CV)

FRAGSTATS outputs... and outputs... and



	A	B	N	O	P	Q	R	S	T	U
1		TYPE	PARA_RA	PARA_SD	CONTIG_MN	CONTIG_RA	CONTIG_SD	CPLAND	CAI_MN	CAI_RA
2	Mount Mitchell	Deciduous Forest	1153.3005	279.9088	0.1468	0.8566	0.1878	38.2294	1.485	63.9787
3	Mount Mitchell	Mixed Forest	1159.9451	301.4044	0.1795	0.8588	0.2067	8.0281	2.3464	66.5021
4	Mount Mitchell	Evergreen Forest	1172.4138	251.4976	0.1413	0.8563	0.166	2.2972	0.8415	62.069
5	Mount Mitchell	Pasture/Hay	1071.0383	296.9432	0.1601	0.7814	0.2001	0.0565	1.6643	52.459
6	Mount Mitchell	Row Crops	828.2828	177.6583	0.0658	0.6061	0.1116	0.0066	0.1433	21.2121
7	Mount Mitchell	Woody Wetlands	333.3333	84.4652	0.0144	0.1667	0.0441	0	0	0
8	Mount Mitchell	Bare Rock/Sand/Clay	444.4444	154.3523	0.0413	0.2778	0.0854	0	0	0
9	Mount Mitchell	Open Water	740.7407	202.9331	0.0757	0.4815	0.1211	0	0	0
10	Mount Mitchell	Emergent Herbaceous Wetlan	0	0	0.0556	0.1111	0.0556	0	0	0
11	Mount Mitchell	Low Intensity Residential	1152.5926	269.4509	0.1415	0.8519	0.1857	0.0803	1.663	64
12	Mount Mitchell	Urban/Recreational Grasses	837.6068	328.4766	0.1482	0.5983	0.2295	0.0044	4.0293	17.9487
13	Mount Mitchell	Commercial/Industrial/Transpo	1087.3016	322.5149	0.1273	0.7897	0.2292	0.0233	4.5455	50
14										
15										
16		TYPE	PARA_RA	PARA_SD	CONTIG_MN	CONTIG_RA	CONTIG_SD	CPLAND	CAI_MN	CAI_RA
17	Silk Hope	Deciduous Forest	1080.4598	311.5206	0.1877	0.7945	0.2148	13.5416	2.8872	55.2147
18	Silk Hope	Mixed Forest	966.6667	243.7458	0.1494	0.6892	0.1591	0.5879	0.5789	36.7347
19	Silk Hope	Pasture/Hay	1192.9825	361.5605	0.2629	0.8813	0.2558	11.3315	6.3187	71.1911
20	Silk Hope	Row Crops	1152.6104	341.8386	0.2215	0.8474	0.237	1.4576	4.1978	65.0602
21	Silk Hope	Evergreen Forest	1242.1652	324.5019	0.1895	0.9244	0.2241	5.9006	3.5937	81.1111
22	Silk Hope	Open Water	866.6667	288.4497	0.1886	0.5833	0.1845	0.0076	0.6724	22.2222
23	Silk Hope	Woody Wetlands	909.0909	250.719	0.0871	0.6667	0.1675	0.0349	0.9453	31.8182
24	Silk Hope	Bare Rock/Sand/Clay	666.6667	154.8014	0.044	0.4444	0.0909	0	0	0
25	Silk Hope	Emergent Herbaceous Wetlan	666.6667	135.7141	0.0292	0.4333	0.0773	0	0	0
26	Silk Hope	Low Intensity Residential	750	209.4783	0.0865	0.5208	0.1401	0.0022	0.4224	12.5
27	Silk Hope	Commercial/Industrial/Transpo	805.5556	257.5688	0.1552	0.5764	0.1752	0.0027	1.2966	12.5
28	Silk Hope	Transitional	1207.333	600.887	0.4451	0.8953	0.4451	1.1873	36.2572	73.3741
29										
30										
31		TYPE	PARA_RA	PARA_SD	CONTIG_MN	CONTIG_RA	CONTIG_SD	CPLAND	CAI_MN	CAI_RA
32	Southwest Durham	Deciduous Forest	1113.5802	271.2288	0.1463	0.8189	0.1826	3.6649	1.482	57.7778
33	Southwest Durham	Mixed Forest	871.7949	210.153	0.1133	0.6154	0.1316	0.0855	0.1379	23.0769

How to use the metrics:

Landscape pattern metrics used as “response variable”

(or dependent)

Forest fragmentation $y = (x)$ Some action or factor

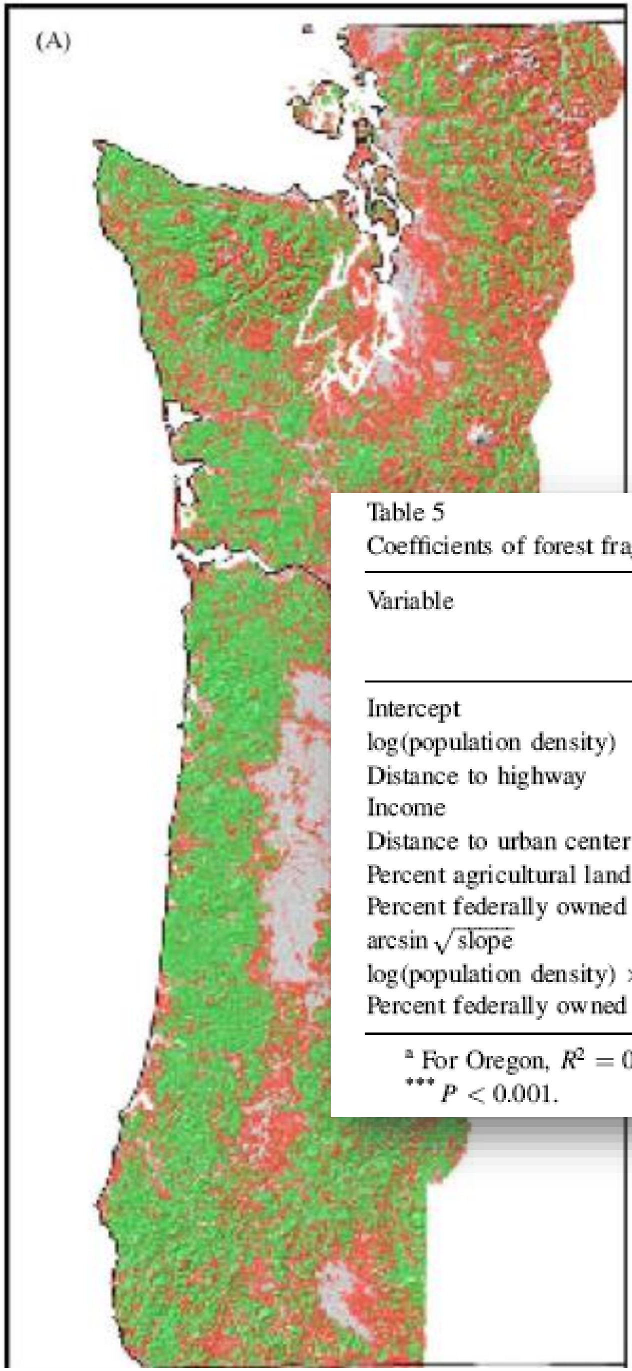
e.g. how will clear-cuts affect forest connectivity?

Landscape pattern metrics used as “predictor variables”

(independent or driving)

Bird diversity $y = (x)$ Patch shape

e.g. What aspect of patch configuration best explains bird diversity?



Correlations of fragmentation with social and physical variables in the PNW

Fragmentation (y) = (x) other factors

Table 5

Coefficients of forest fragmentation index linear regression models for western Oregon and western Washington[a]

Variable	Western Oregon		Western Washington	
	Coefficient	t-Value	Coefficient	t-Value
Intercept	33.430***	15.720	19.062***	9.713
log(population density)	9.854***	13.193	12.315***	15.905
Distance to highway	−0.302***	−3.977	−0.055	−0.746
Income	0.024	0.547	0.140***	3.463
Distance to urban center	−0.016	−1.775	−0.006	−0.508
Percent agricultural land	0.297***	18.327	0.213***	7.159
Percent federally owned	−0.249***	−6.969	−0.184***	−7.472
arcsin $\sqrt{\text{slope}}$	−80.684***	−13.643	−45.836***	−8.101
log(population density) × distance to highway	−0.427***	−6.256	−0.357***	−5.924
Percent federally owned × arcsin $\sqrt{\text{slope}}$	0.890***	8.556	0.782***	11.076

[a] For Oregon, $R^2 = 0.90$ and $n = 605$. For Washington, $R^2 = 0.68$ and $n = 841$.

*** $P < 0.001$.

Butler, B.J., J.J. Swenson, and R. Alig. 2004. Forest Fragmentation in the Pacific Northwest: Quantification and Correlations. Forest Ecology and Management 189:363-373.

Why characterize regional pattern

- To compare landscapes
  - Different places (e.g. 2 different places, similar forest types, 2 different disturbance types)
  - Over time (trajectories of change; more fragmented, less?)
  - Alternate management scenarios

Using only metrics

- To look deeper into processes
  - What is causing the pattern?
  - How does the pattern affect the community?

Comparing metrics to other data

Summary

- Fragmentation has varied ecological impacts
  - Different temporal and spatial scales
  - Magnitudes vary by species

- Fragmentation can be quantified several ways
  - Patch attributes (size, shape, edge effects, distribution)
  - Landscape attributes (total area, summary stats)