

# A critique of patch-based landscape indicators for detection of temporal change in fragmentation

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**2009 European Conference of the International Association of Landscape Ecology  
European Landscapes in Transformation - Challenges for Landscape Ecology  
and Management**

**Symposium No 6: The third and fourth dimensions of landscapes**



# Overview

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1. A personal account (history) of how the 3<sup>rd</sup> and 4<sup>th</sup> dimensions of landscape have been overlooked.
2. A critique of patch-based metrics for landscape change detection;
  - difficult to interpret, counterintuitive results;
  - fix the observation scale;
  - don't apply when the feature of interest is the matrix.
3. A solution – landscape pattern metrics that can be used for change detection.
4. Thoughts on the term fragmentation.



# History

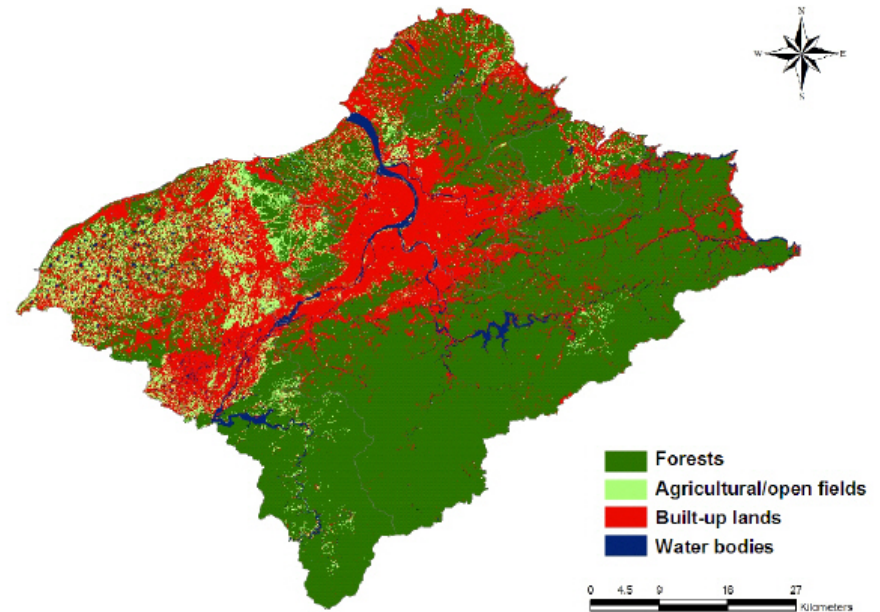
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O'Neill, RV et al. 1988. Indices of landscape pattern. *Landscape Ecology* 1:153-162.

Shannon (dominance & contagion), fractal dimension, and land-cover proportion



**Ecology**



**Also Ecology**

# History

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O'Neill, RV et al. 1988. Indices of landscape pattern. *Landscape Ecology* 1:153-162.

Shannon (dominance & contagion), fractal dimension, and land-cover proportion

SPAN (Turner 1988)

R.LE (Baker and Cai 1993)

Fragstats (McGarigal and Marks 1995)

Forman RTT, Godron M. 1981. Patches and structural components for a landscape ecology. *BioScience* 31:733-740.



# History

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Troll, C. 1970. Landscape ecology (Geoecology) and biogeocenology – a terminological study. *Geoforum* 1:9-18

Landschaft ecology – combine the ‘regional differentiation of the earth’s surface’ (horizontal) with the ‘functional characteristics of a site’ (vertical).

... help ecologists discover aerial photography

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Hoechstetter, S., **Walz, U.**, Dang, L.H., Thinh, N.X. 2008. Effects of topography and surface roughness in analyses of landscape structure – A proposal to modify the existing set of landscape metrics. *Landscape Online* 1, 1-14. DOI:10.3097/LO.200801

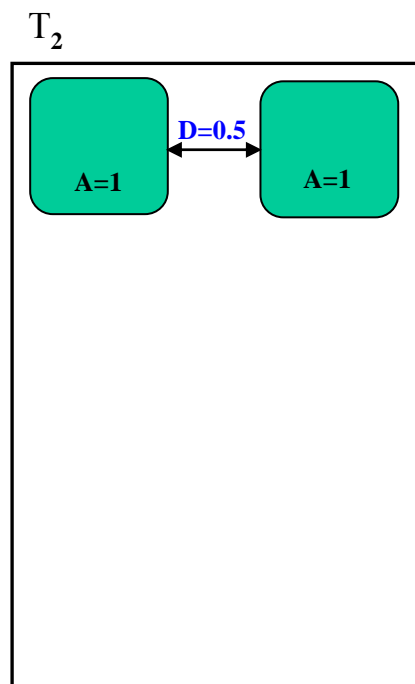
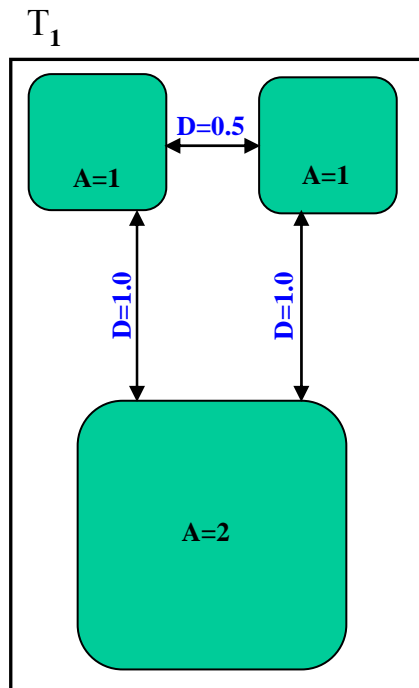


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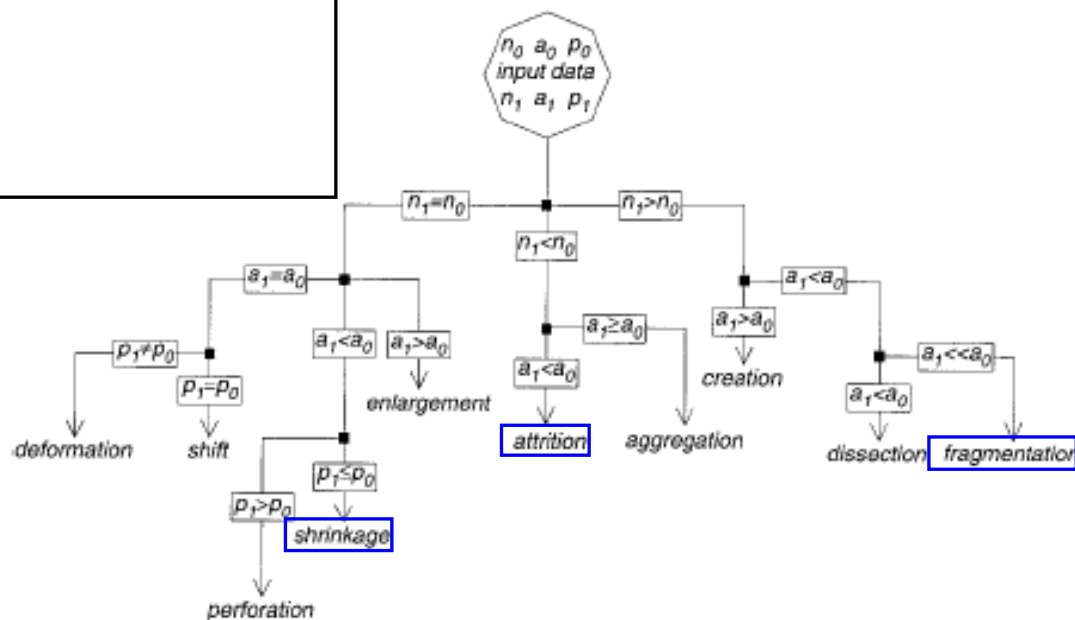


# Critique – hard to interpret

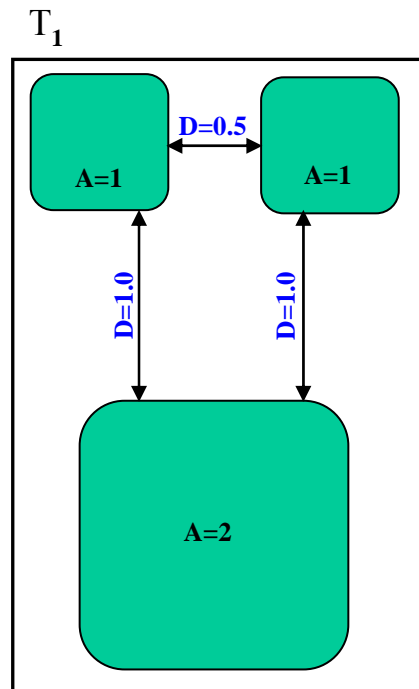


Change over time

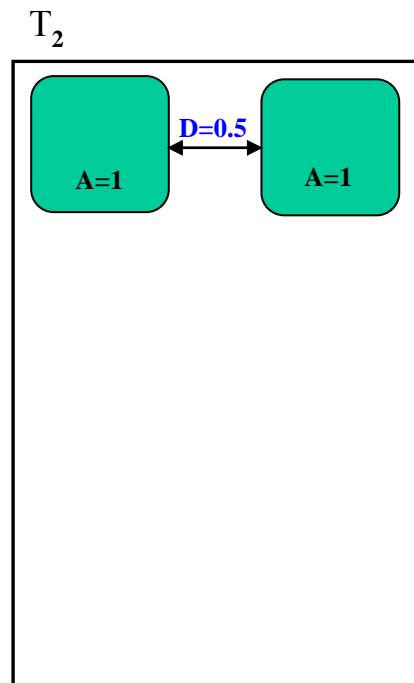
1. Hard to interpret; is it attrition, fragmentation, or shrinkage?



# Critique – hard to interpret



Mean patch size = 1.33  
Mean inter-patch distance = 0.83  
Number of patches = 3



Mean patch size = 1.0  
Mean inter-patch distance = 0.5  
Number of patches = 2

## Change over time

1. Hard to interpret; is it attrition, fragmentation, or shrinkage?
2. Produces counterintuitive results; average patch size decreases (as expected), but average inter-patch distance and number of patches also decrease (counterintuitive).

# Critique – hard to interpret

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Fragmentation index	T <sub>1</sub>	T <sub>2</sub>	%Change
Number of patches	3304.0	4702.0	42.3
Average inter-patch distance (m) (perimeters)	56.4	54.8	-2.8
Average patch size (ha)	5.1	3.3	-35.9
Average edge-to-area ratio (km/km <sup>2</sup> )	62.2	54.9	-11.8

T<sub>1</sub> and T<sub>2</sub> = with and without roads in land-cover map (simulates road building).



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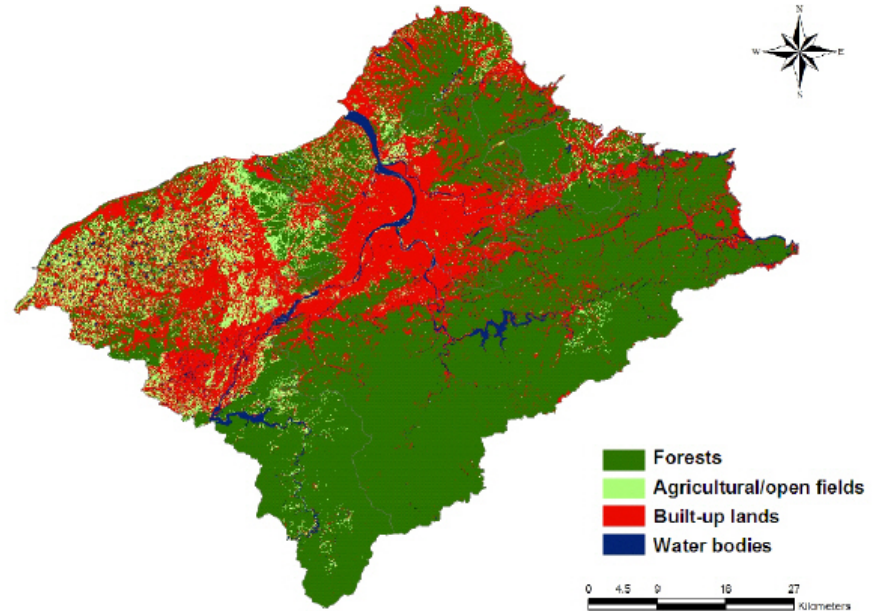


# Critique – scale (fix observation scale)

## Scale is an important ecological attribute



Importance of scale less obvious?



Importance of scale more obvious?

- downwind precipitation
- water quality
- hydrology
- habitat

# Critique – change and scale

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**Blaschke**, T. 2001. Continuity, complexity and change: A hierarchical geoinformation-based approach to explore patterns of change in a cultural landscape in Germany. In: Mander U. and Palang H. (Eds.) Multifunctional Landscapes: Continuity and Change. WIT Press.

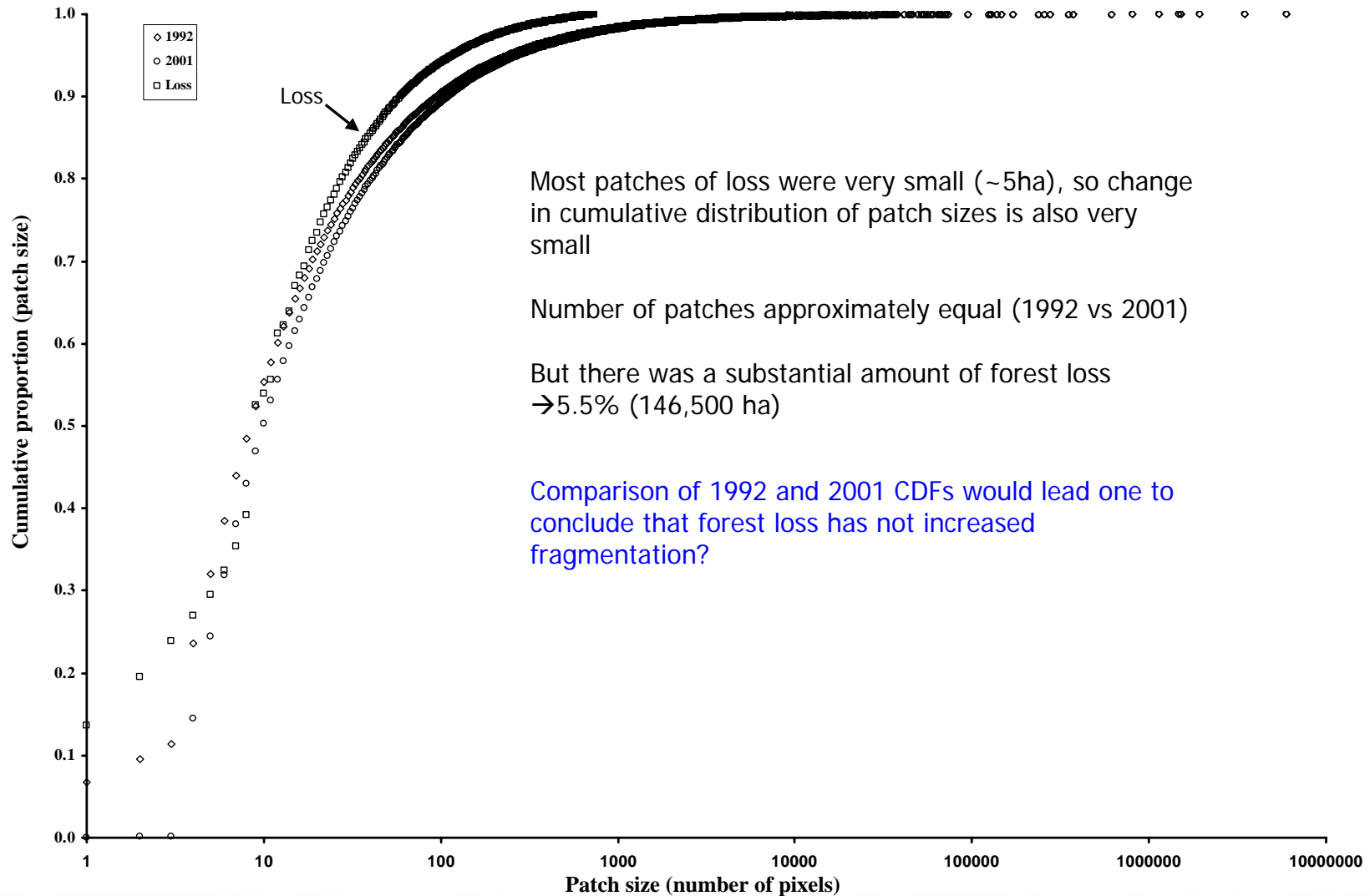
Hay GJ, **Blaschke** T, Marceau DJ, Bouchard A. 2003 A comparison of three image-object methods for the multiscale analysis of landscape structure. ISPRS Journal of Photogrammetry & Remote Sensing 57:327– 345

**Drăgut** L, Schauppenlehner T, Muhar A, Strobl J, **Blaschke** T. 2009. Optimization of scale and parameterization for terrain segmentation: An application to soil-landscape mapping. Computers & Geosciences doi:10.1016/j.cageo.2009.10.008



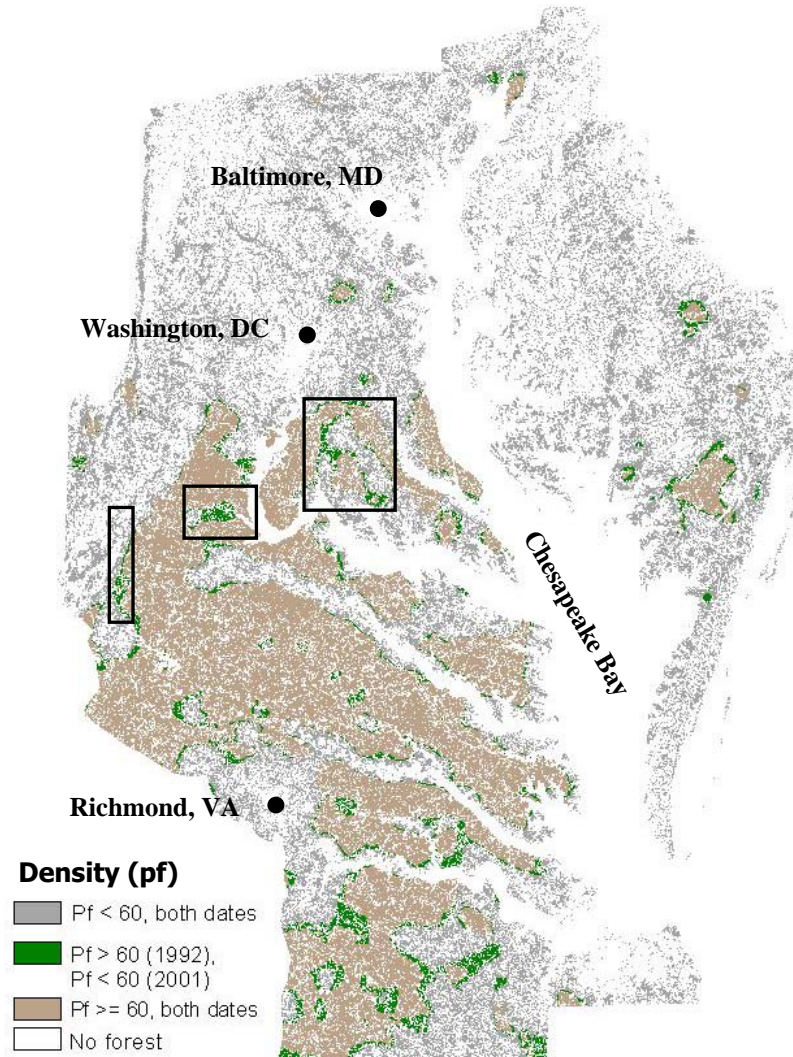
# Critique – scale (fix observation scale)

Change in cumulative distribution of forest patch size – Chesapeake Bay region (1992-2001)



# Critique – change and scale

Density of forest at 5300ha  
dominant forest = 60%



A 5.5% loss of forest is ...

- 1) Erosion at the edges of large areas of dominant forest.
- 2) Perforation of large areas of dominant forest
- 3) Isolation of large areas of dominant forest.

It is difficult to see these patterns of change when using the patch conceptual model.

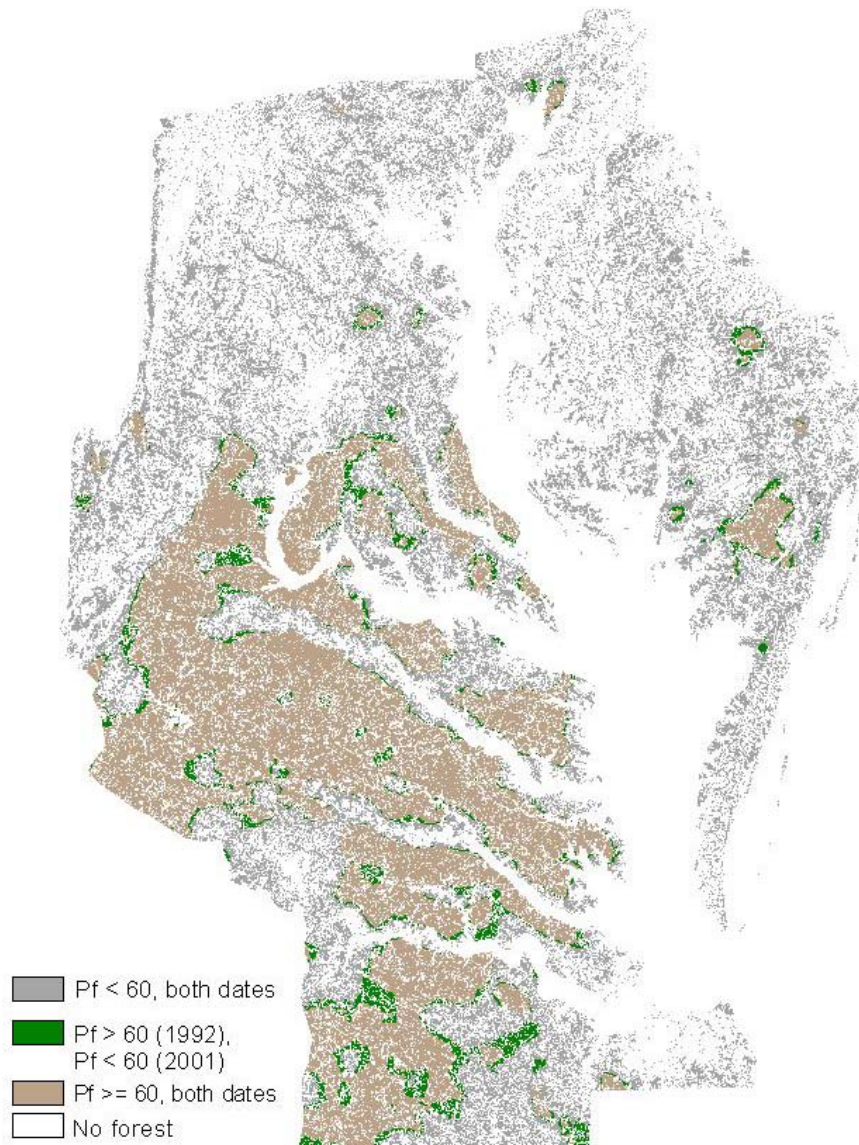
Forest loss is changing the spatial scale at which forest occurs in and dominates the landscape.

Wickham et al. 2007. *Landsc. Ecol.*



# Critique - change and scale

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A sidebar about change ...

There are two interacting spatial patterns:

- 1) the extant pattern of forest
- 2) the pattern of change

*A priori* prediction of the effect of change may be more in the realm of monitoring

There would have been no loss of large-scale (5300ha) dominant forest if forest loss had predominated (or been constrained) in the northern half of the region

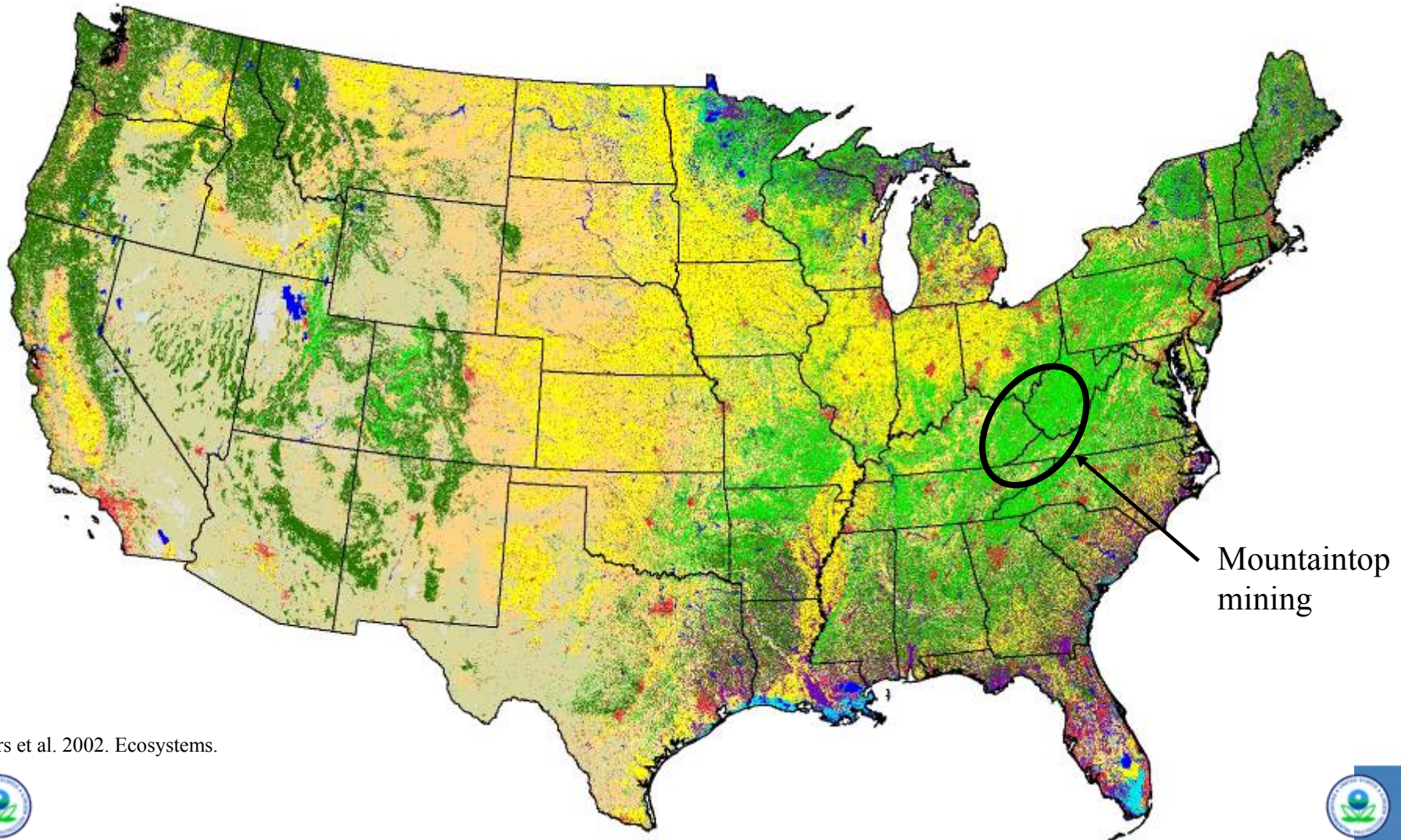
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# Critique – doesn't apply (matrix)

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The patch-matrix conceptual only applies to 3 of 10 forested locations in the US.



Mountaintop  
mining

# Critique – doesn't apply (matrix)

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**Mountaintop mining:** coal mining and reclamation that remove entire coal seams running through the upper fraction of a mountain, ridge, or hill by removing all of the overburden, and creating a level plateau or gently rolling contour. Exceptions are provided so that reclamation does not have return the land to its approximate original contour (30 CFR 716.3).



Practice arose because of amendments to the 1990 Clean Air Act



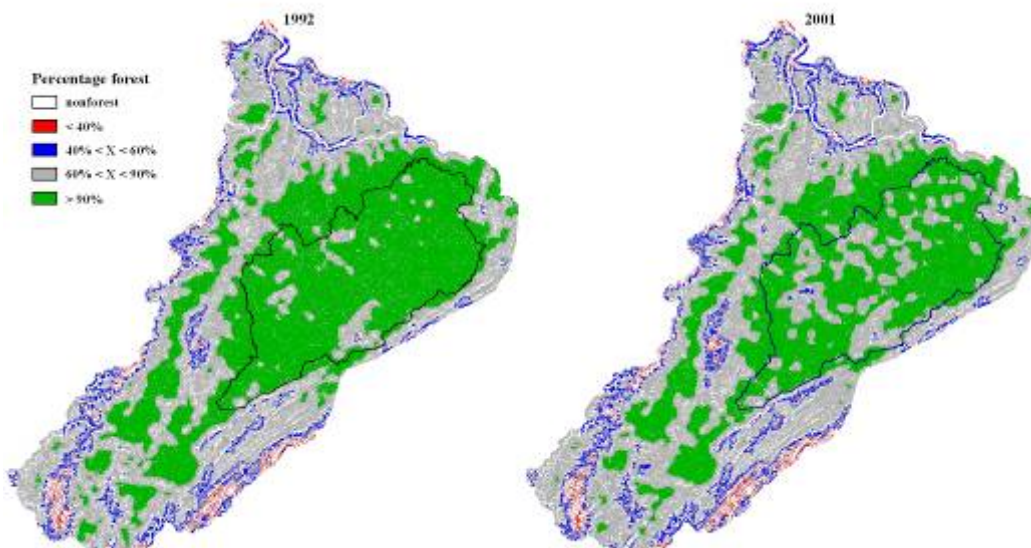
# Critique - doesn't apply (matrix)



## NEPA, Env. Impact Statement

Ratio of Interior Forest Loss to Forest Loss

Forest Type	Scale ha	Ratio
Cove	2	1.7
	7	2.8
	65	3.3
	590	5.8
	5314	8.1
Mix.Meso.	2	1.7
	7	1.9
	65	2.5
	590	3.9
	5314	5.1



Change in green shows loss of interior forest at 5300ha scale

Wickham et al. 2007 Landsc. Ecol.



RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions



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# A solution

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1. Don't use patch-based landscape metrics for change detection when they don't apply
2. Only three (3) measures are needed for change analyses
  - a. amount (proportion)
  - b. context (relative distributions of features at a specified scale)
  - c. structure (edge)?



# A solution

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## Amount

- Pattern does not exist in the absence of amount; landscape pattern metrics have no meaning if there is nothing to measure.
- Amount is unambiguously interpretable over time; amount can only decline when there is a net loss and increase when there is a net gain.
- Most fragmentation metrics are correlated with amount.

	PctFor
F_AWPatSiz	0.92
F_Conn	0.91
F_EARat	-0.90
F_PatSiz	0.81
F_NumPat	0.66
F_PARatAdj	0.53
F_TopoD	0.33
F_PAFract	-0.06

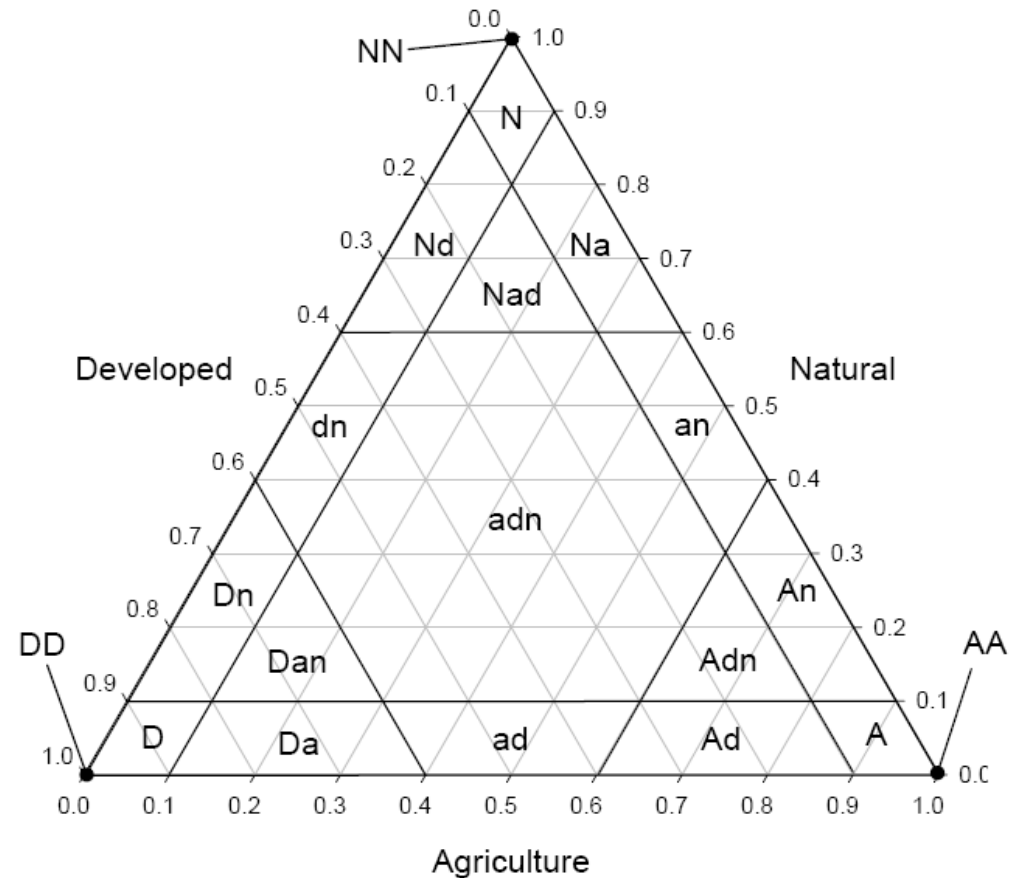
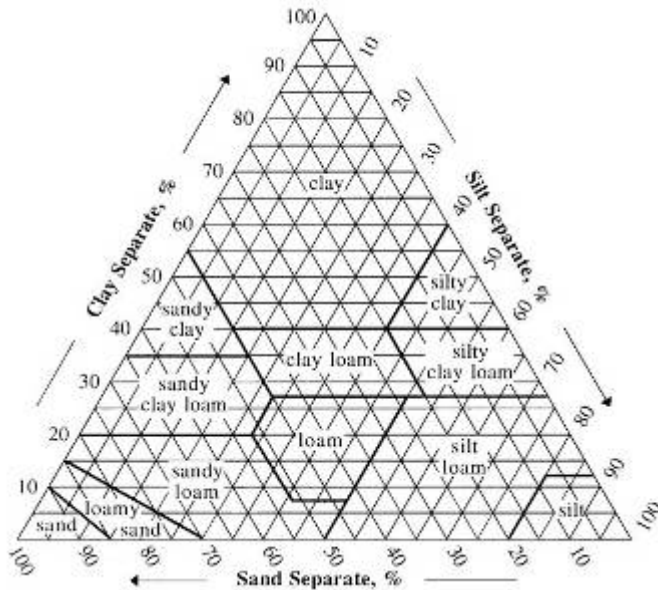
(Source: Riitters et al. 2006)



# A Solution

## Context

- The condition of a feature of interest (habitat) probably depends on its setting.
- A change in setting likely results in a change in condition

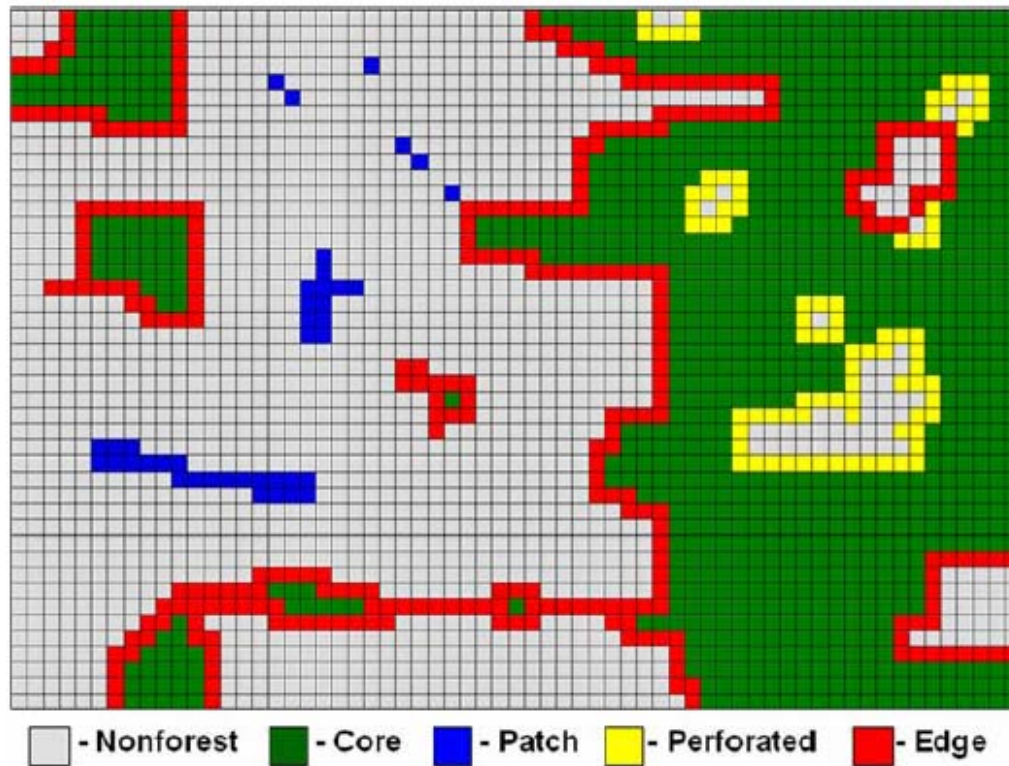


# A Solution

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## Structure (Edge)

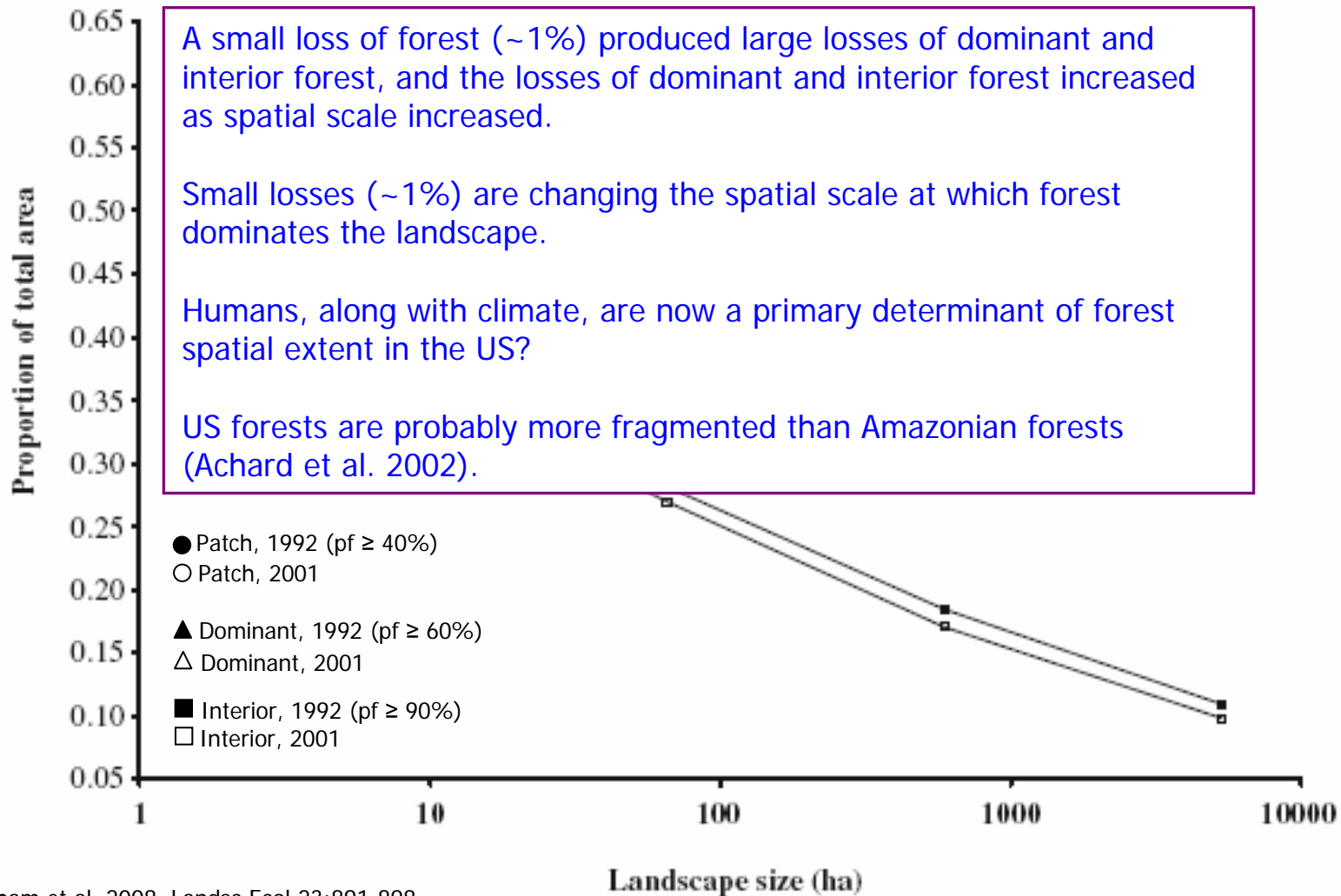
- An important landscape attribute that has not been fully studied.
- Harper et al. (2005) Cons. Biol.; Laurance (2008) Biol. Conserv.



Vogt et al. 2007. Landsc. Ecol. 22:171-177

# A Solution – an example using only amount

Temporal changes in fragmentation of continental US forests at multiple scale



Wickham et al. 2008. Landsc Ecol 23:891-898.



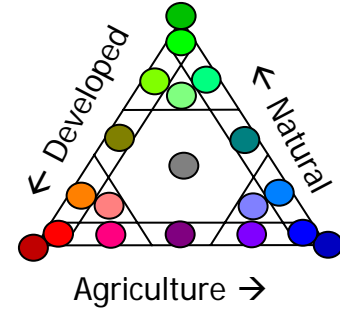
RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions



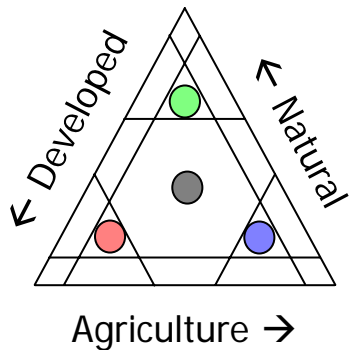
# A solution – an example combining amount and context

Use land-cover change and Markov models to examine forest change (amount) as a function of a shifting landscape mosaic (context)

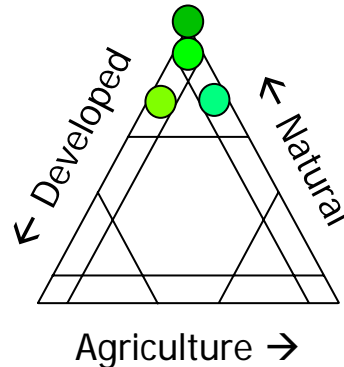


1. Assess landscape change (context) using tripolar chart as landscape classification model.
2. Assess forest change (amount) within the context of landscape change. Expands the 4-class (from-to) forest change.

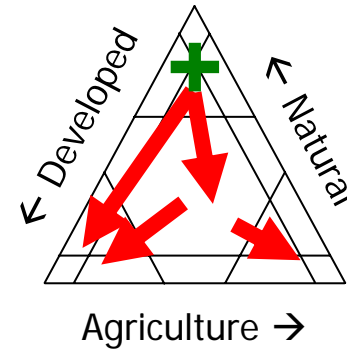
## Results



Forest is at highest risk in the most heterogeneous landscapes (loss  $\geq 20\%$ )



Forest gain is concentrated in natural landscapes (gain  $\sim 0.1\%$ )



Summary – forest dynamics depended on the dynamics of the landscape in which they were contained.

# Fragmentation

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Wilcove DS, McLellan CH, Dobson AP. 1986. Habitat fragmentation in the temperate zone. In. M. Soulé (Ed.), Conservation Biology: Science of Scarcity and Diversity. Sinauer Associates, Sunderland, MA.

→ Fragmentation occurs when a large expanse of habitat is transformed into a number of smaller patches of smaller total area isolated from each other by a matrix of habitats unlike the original.

Lindenmayer DB, Fischer J. 2006. Tackling the habitat fragmentation pantheon. TREE 22.

→ Unproductive debates, careful separation (loss, isolation), effective mitigation

When has loss not resulted in fragmentation (isolation)?

→ what are those odds?

Did island biogeography ever formally incorporate and consider change over time?



# Fragmentation

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MacArthur RH, Wilson EO. 1967. The theory of island biogeography. Princeton U. Press

## Table of Contents

→ (1) The importance of islands; (2) Area & number of species; (3) Further explanation of area-diversity patterns; (4) The strategy of colonization; (5) Invasibility & the variable niche; (6) Stepping stones & biotic exchange; (7) Evolutionary changes following colonization; (8); Prospect.

Island biogeography was not about landscape change; it was about moving biogeography from descriptive 'naturalism' to theory & hypothesis testing (population ecology).

I think the extension to landscape (and change) came from page 4 and page 140

→Page 4 showed the Cadiz Township forest loss, and p 140 talked (a little bit) about habitat as islands (stepping stones).

Might it be more useful to view fragmentation and loss as synonyms, rather than view fragmentation as a confusing term (panchreston) that has spawned unproductive debates?



# Questions?

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... but first some deductive reasoning

Observation #1: the Japanese eat less fat and more fish than Americans & Brits; they have fewer heart attacks.

Observation #2: the French have the same diet as Americans & Brits, but drink more red wine; they also have fewer heart attacks.

Deductive reasoning: Its not your diet, it is speaking English that leads to heart attacks!

Source: “Click and Clack” the Tap’n Brothers, 1 Harvard Square, Cambridge MA, USA

