- Status 2011
- Fragmentation Index
- Landscape Units, Subunits & Types
- Urban Growth Projections & Energy Infrastructure Impacts
- Forest Losses
- Landscape Configuration Change

The effects of future urbanization and energy infrastructure expansion on forest fragmentation

Alfonso Yáñez Morillo
CLUS Research Analyst

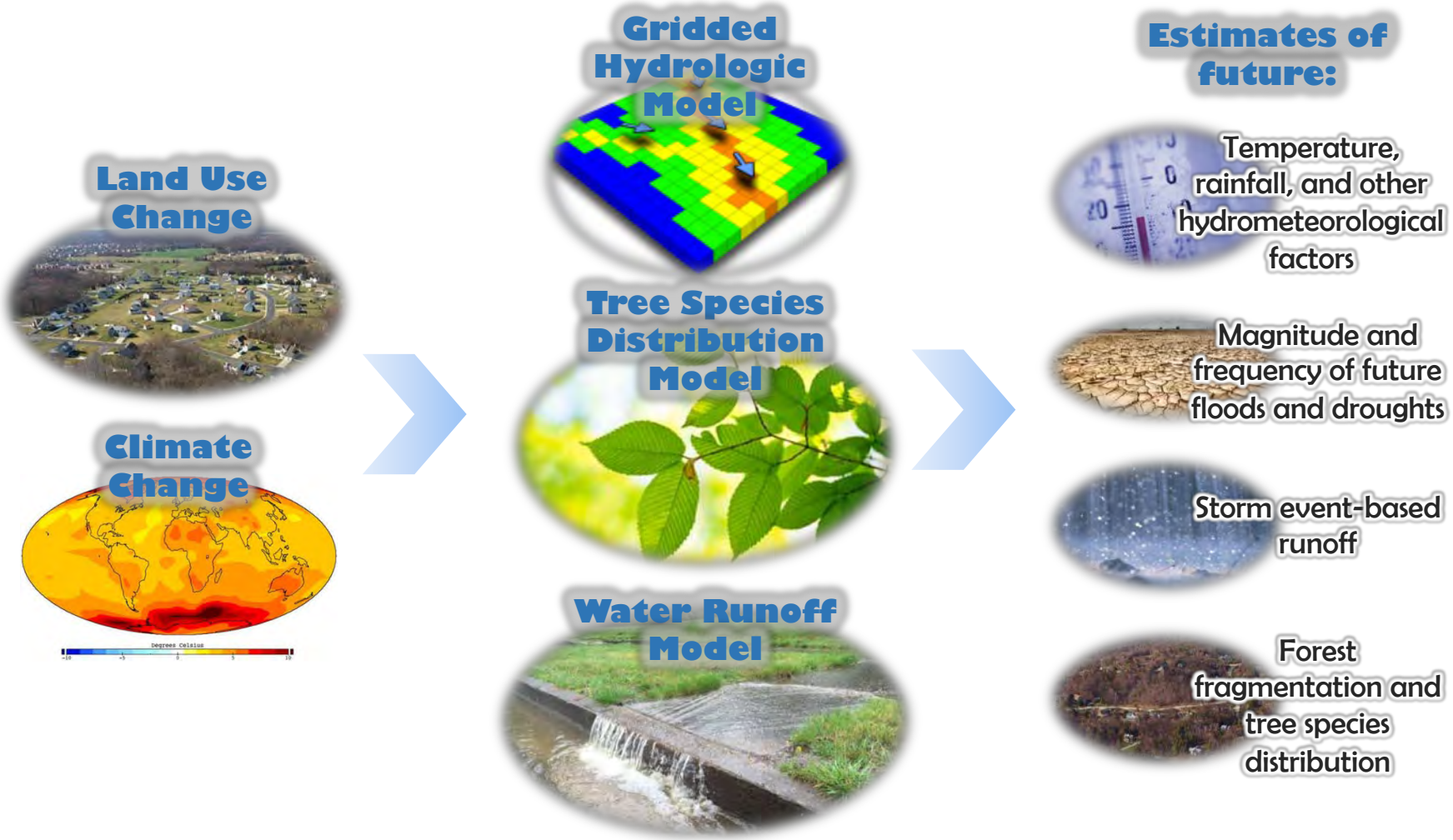
Dr. Claire Jantz
CLUS Director
Antonia Price
CLUS Project Manager

Dr. Scott Drzyzga
Dr. Christopher Woltemade
Dr. Tim Hawkins
CLUS Affiliate Scholars

Dr. Patrick Jantz
Northern Arizona University

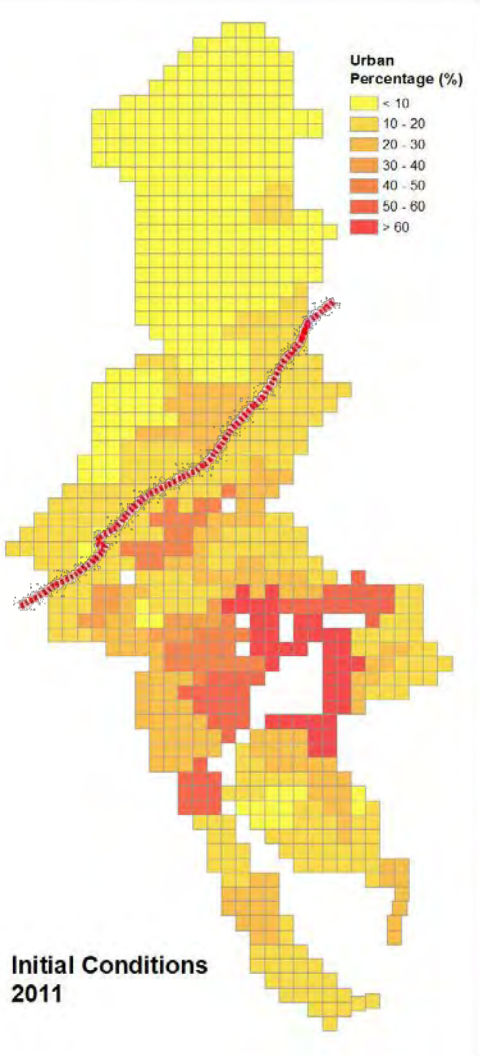
Center for Land Use and Sustainability
Shippensburg University

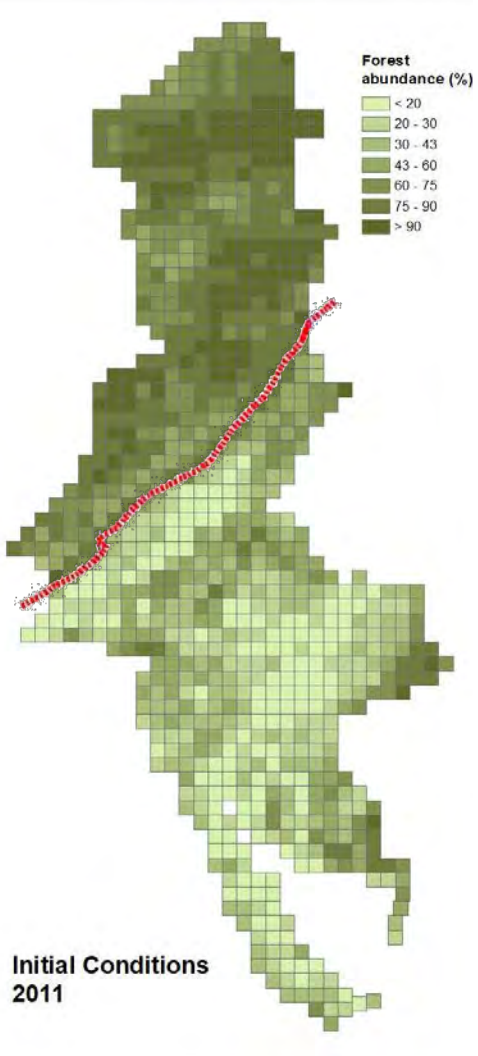
How will forest ecosystems and hydrologic processes in the Delaware River Basin be affected by climate change and land cover change?

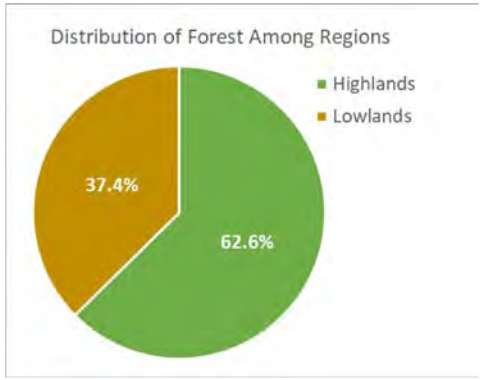


www.drbproject.org

Status at 2011

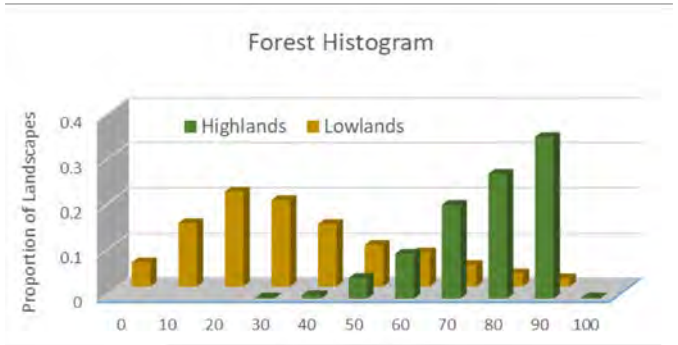


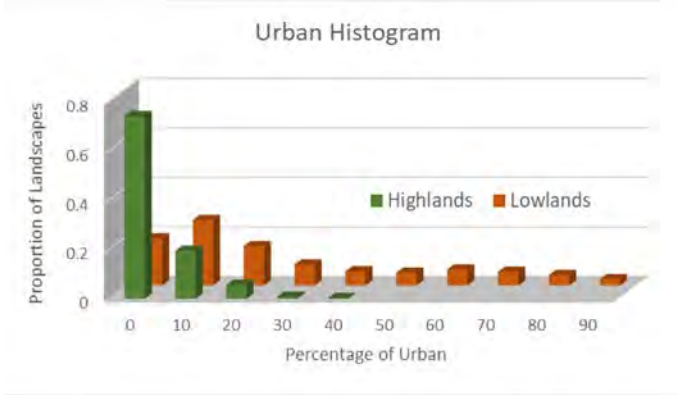




Class	DRB		Highlands		Lowlands	
	Has	*%*	*Has*	*%*	*Has*	*%*
Forest	1,796,146	56.5	1,124,839	80.8	671,307	37.6
Urban	682,620	21.5	102,857	7.4	579,764	32.4

Land use area and its percentage respect of the land in the whole basin and in the two regions.

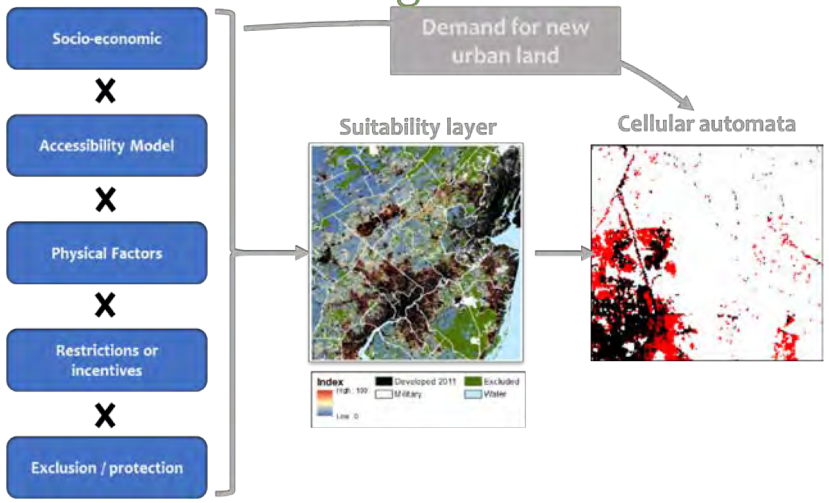




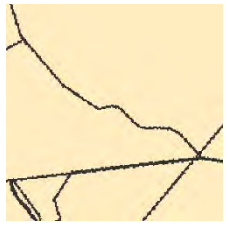
Generating Future Forest scenarios

DELAWARE RIVER BASIN Land Use Dynamics SHIPPENSBURG UNIVERSITY

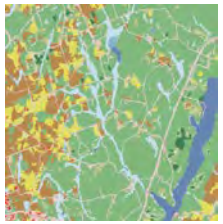
Land Use Change Model:
SLEUTH Modeling Framework



Power Lines



NLCD 2011

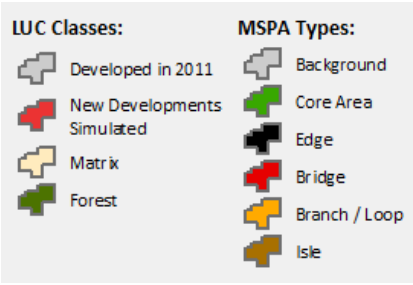


Forest 2011

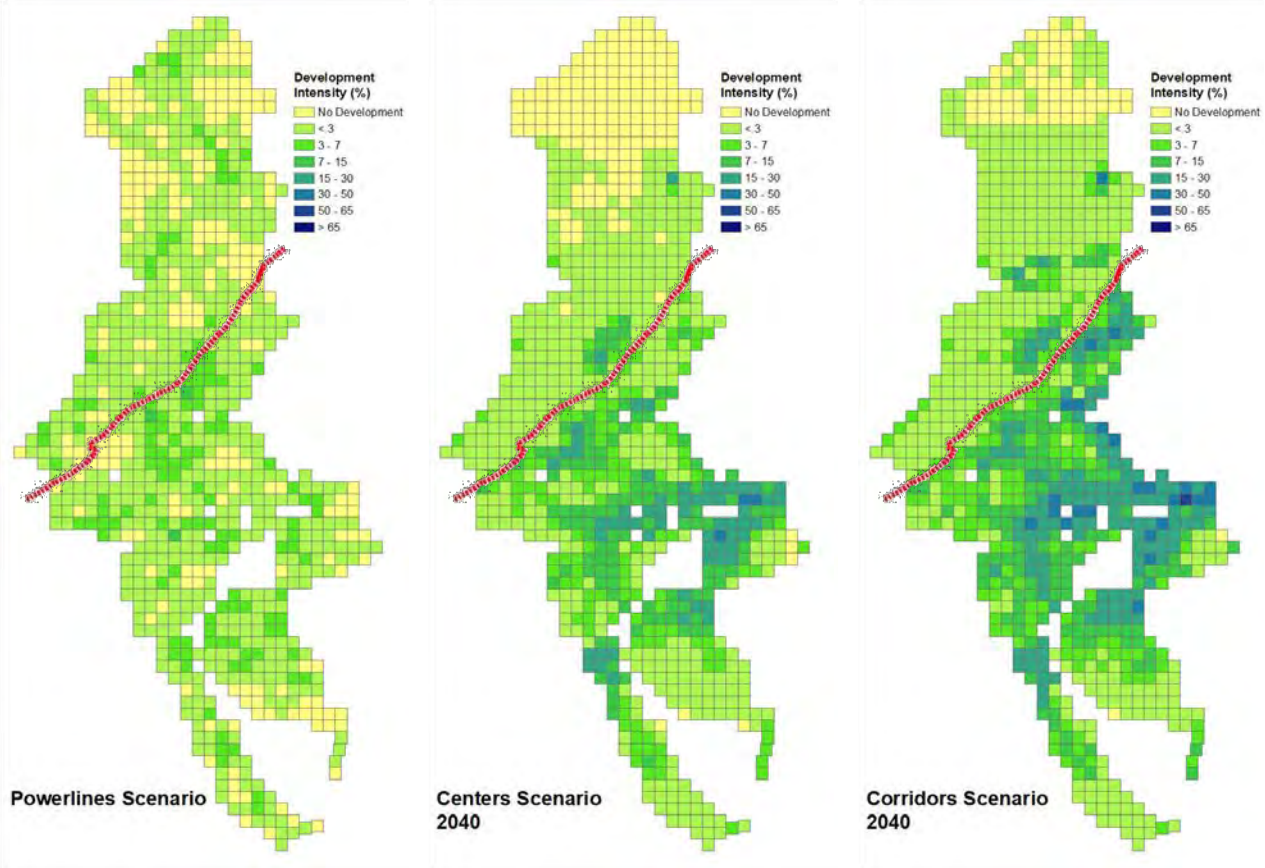
Forest 2100

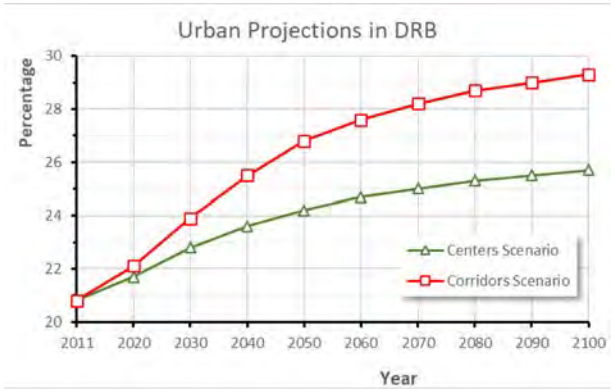
MSPA

Corridors Scenario	Centers Scenario
• *"Sprawl growth"* • Growth potentiated alongside designated corridors (I-84, I-80, I-78, I-476) and new stations for the Lackawanna cutoff. • Public land protected	• ***"Smart growth"***. Conservative approach with more infill growth and concentrated around current centers. • Maximum land protection: public and private land included in PAD-US • Completely protect all slopes >15%
• Strong protection in 100 ft. buffer around high quality streams. • Water and non forested wetlands are not available for growth • Hurricane cat. 4 storm surge. • 100 simulations for each scenario	



Urban & Power line Projections





Scenario	Total growth		Highlands		Lowlands	
	ha	*rate*	*ha*	*rate*	*ha*	*rate*
Corridors	272,018	0.45	40,477	0.07	231,541	0.38
Centers	142,850	0.24	11,459	0.02	131,391	0.22
Power lines	50,629		14,090		36,539	

Annual rate in percentage

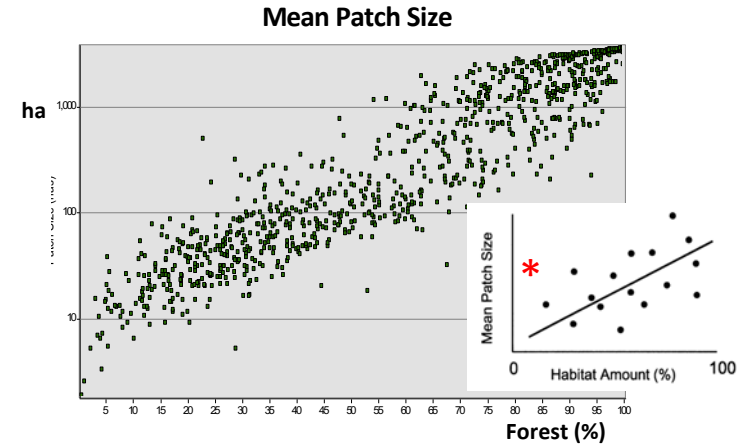
- **Development Intensity:** Percentage of available land in 2011 developed during simulation.
- Intensity average of 13% and maximum of 73% in the most intensive scenario
- Urban growth and affects more the southern landscapes than the highland zone.
- Area affected for future energy transmission infrastructure much less intense than urban growth and is more evenly distributed between zones.

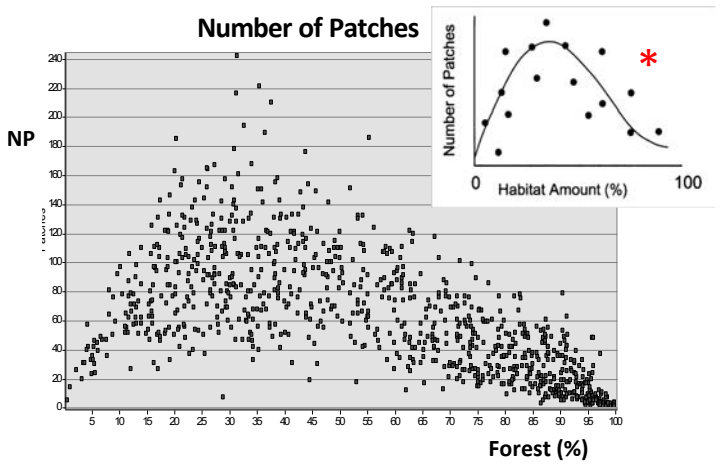
Habitat Fragmentation

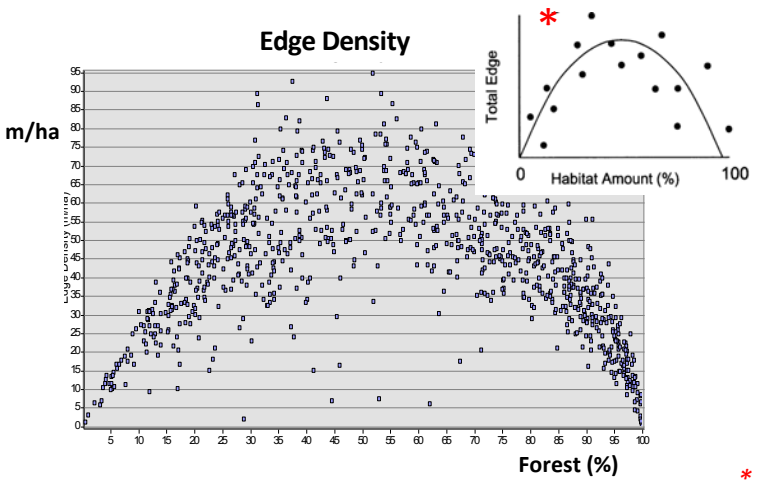
Fragmentation: *"Process during which a large expanse of habitat is transformed into a number of smaller patches of smaller total area" (Wilcove, 1986)*

Fragmentation has implication in four aspects of the habitat pattern:

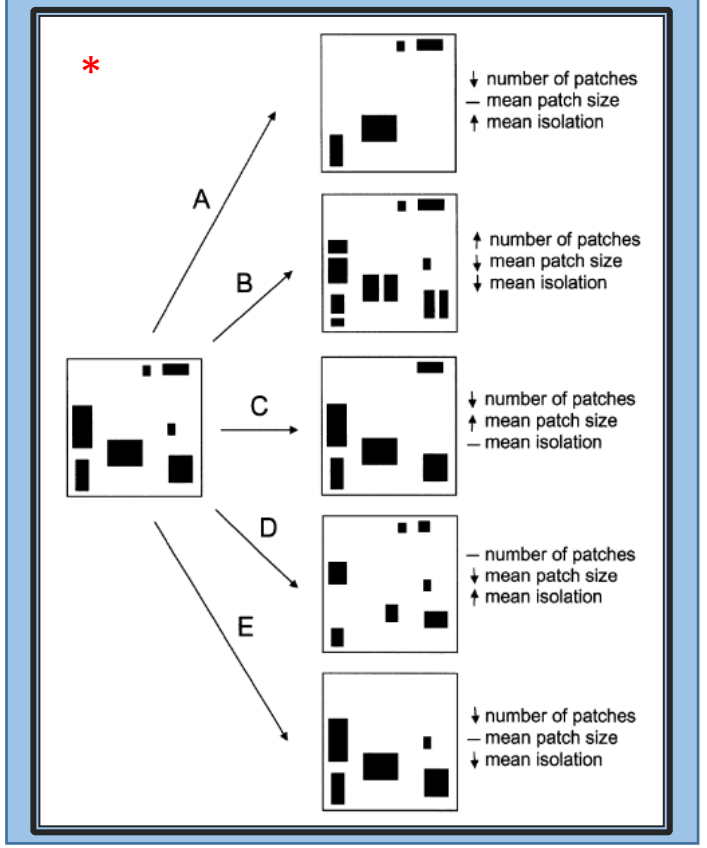
- **Habitat Loss**
- **Number of patches**
- **Size of patches**
- **Isolation of patches**







Same habitat loss may result in different pattern change



* *Figure obtained from* Fahrig, Lenore. "Effects of Habitat Fragmentation on Biodiversity." *Annual Review of Ecology, Evolution, and Systematics* 34 (2003): 487-515. www.jstor.org/stable/30033784.

Quantifying Fragmentation with the Equivalent Area Index

- Look for a Fragmentation measure sensitive to most pattern aspects.
- Structural types can be weighted to transform the habitat area into an equivalent area considering the morphological spatial structure.
- The core coefficient (**α**) is dependent of the patch size making the index more sensible to the distribution of patch sizes.
- Coefficients can be defined with ecological meaning, relating the index with the concept of **habitat quality**.

$$eqArea = \sum (A_i * w_i)$$

A_i: area of structural type i,

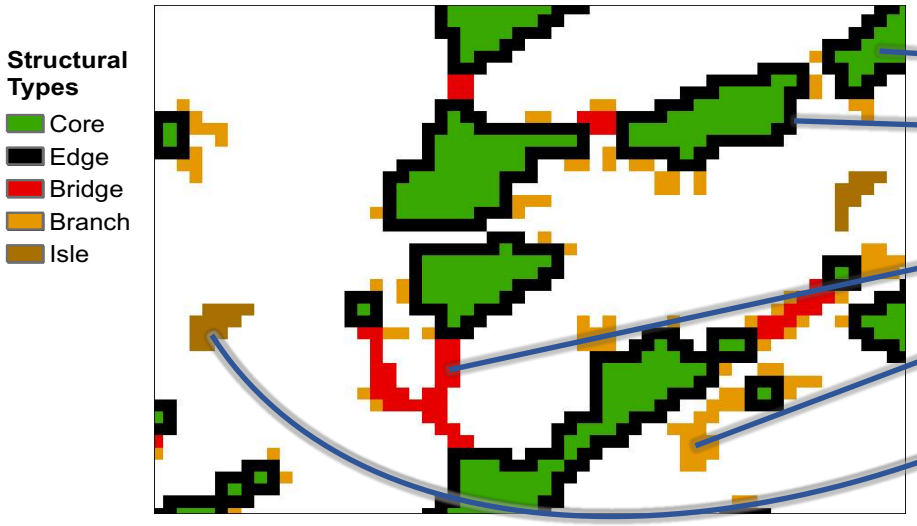
c_i: structural type i coefficient.

$$eqIndex = \frac{\sqrt{eqA(eqA + A)}}{4S}$$

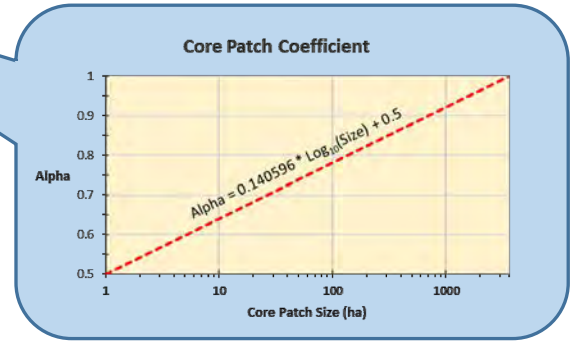
eqA: equivalent habitat area ($eqArea$),

A: total habitat area,

S: Reachable landscape which is the habitat and its surrounding area, defined by a buffer of 500m.



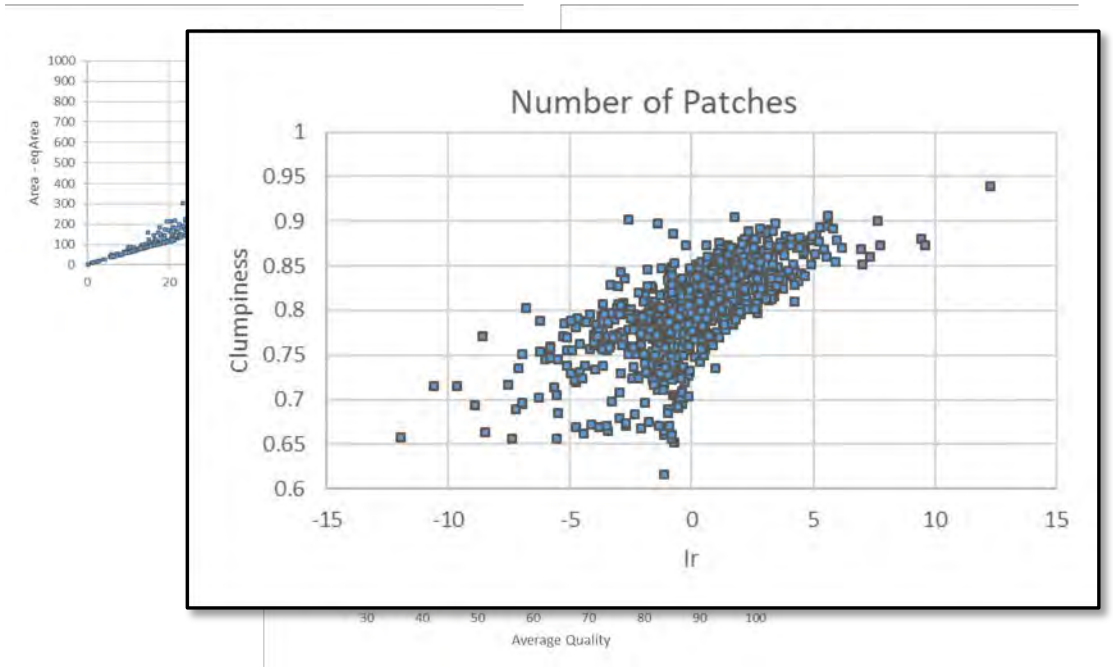
Structural	w_i
Core	α
Edge	0.45
Bridge	0.5
Branch	0.25
Isle	0.1

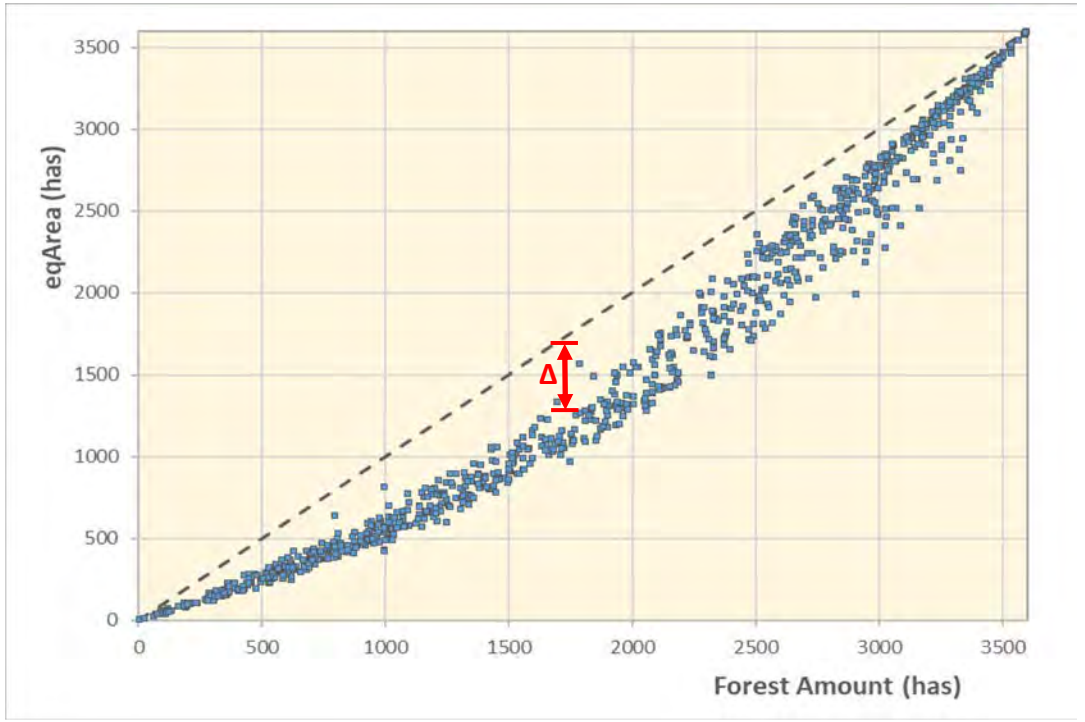


P. Vogt & K. Riitters, 2017: GuidosToolbox: universal digital image object analysis. European Journal of Remote Sensing (TEJR), DOI: http://dx.doi.org/10.1080/22797254.2017.1330650

Interpreting Equivalent Area Index

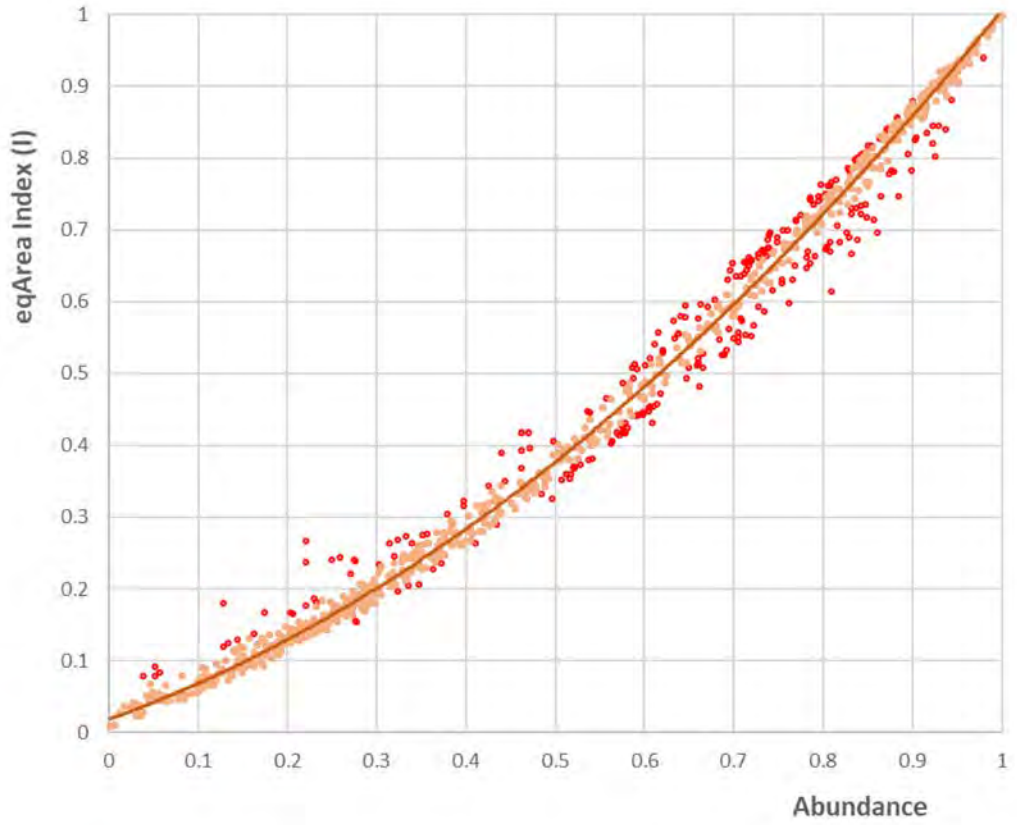
- Fragmentation trend to increase the proportion of non-core types and reduce the core area sizes, the equivalent area in more fragmented landscapes is smaller.
- The difference between forest area and equivalent area could be consider as a measurement of fragmentation.
- It is strongly related with the habitat abundance, as we observe the landscapes in the basin follows a well defined relationship between habitat abundance and equivalent area.



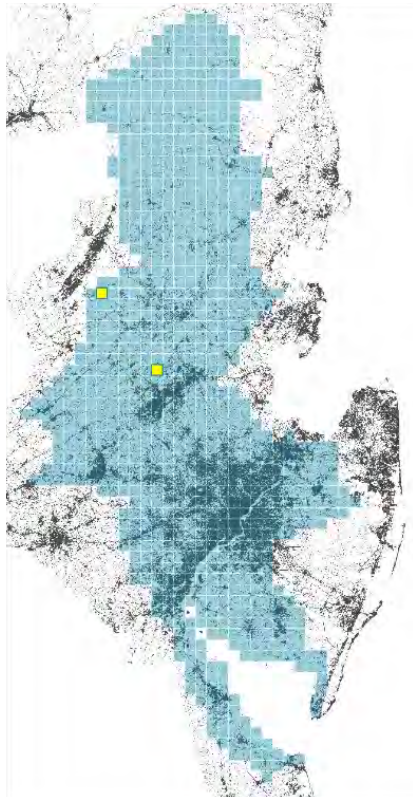


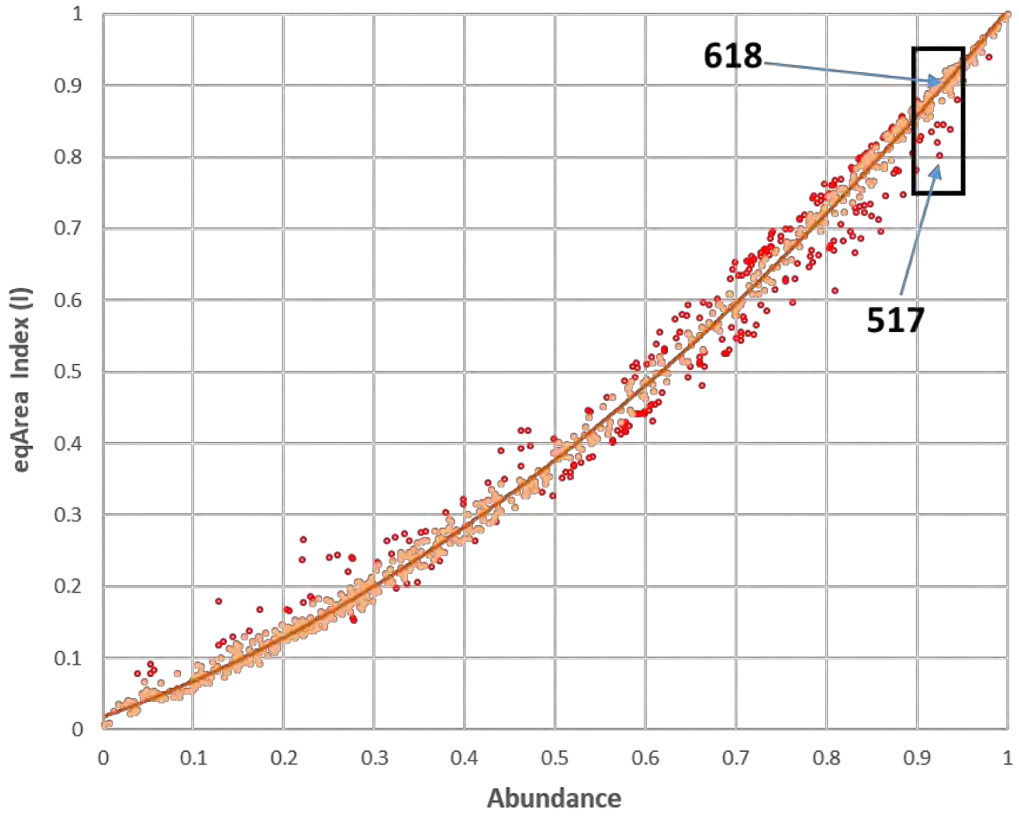
- the equivalent area is a measure related with several aspects of the habitat pattern.
- The shape of the curve is result of the land transformation history in the basin and how the activities have modelled landscapes at different stages.

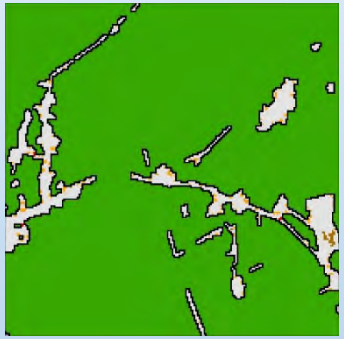
Interpreting Equivalent Area Index



Interpreting Equivalent Area Index



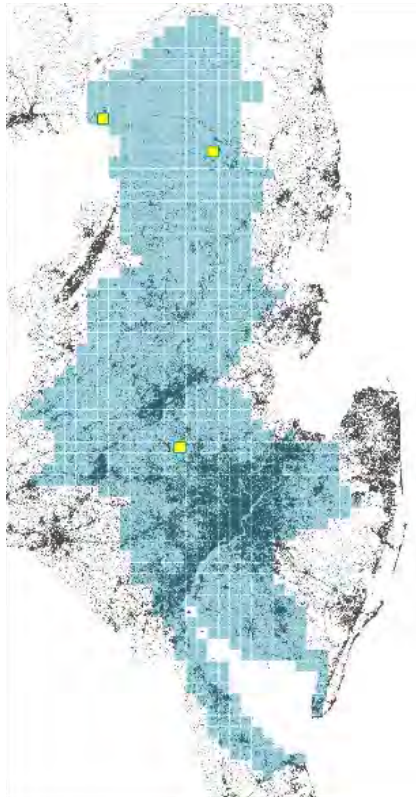


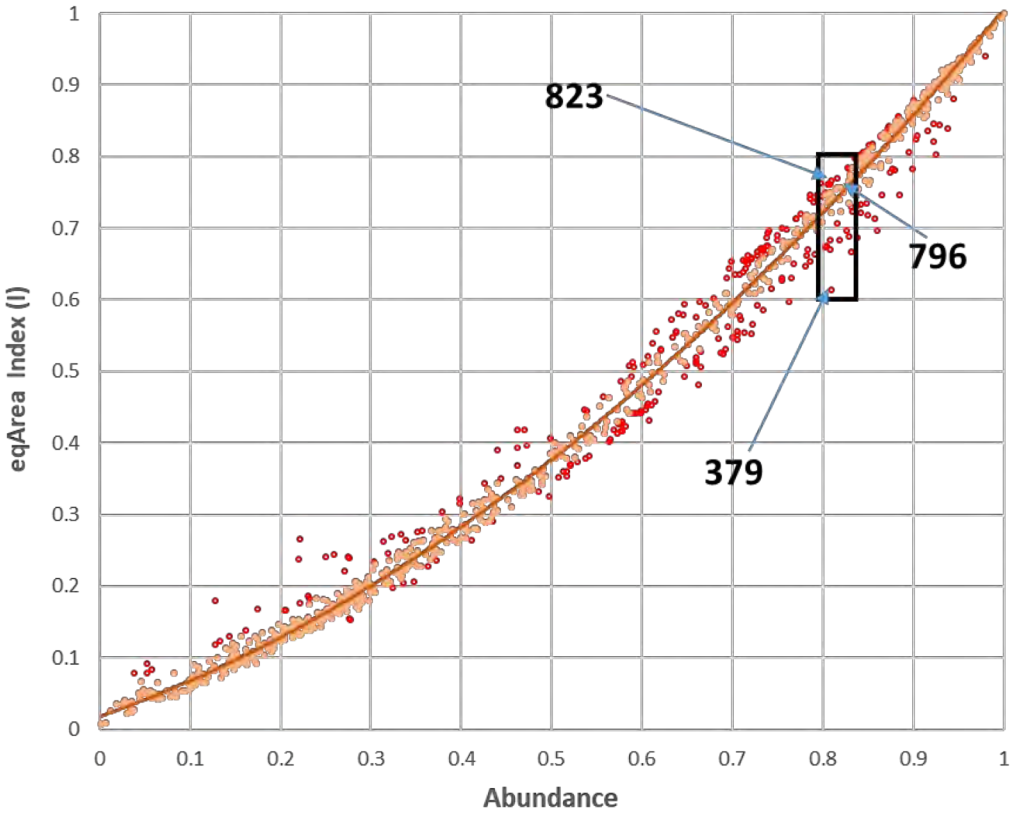


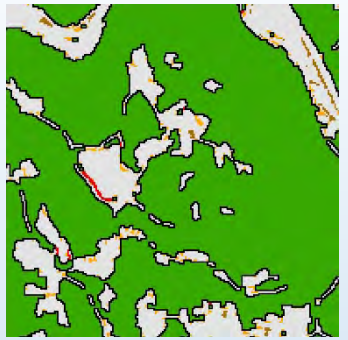
Landscape 618
P= 0.929
I = 0.904
Ir = 0.404

Landscape 517
P= 0.925
I = 0.802
Ir = -9.237

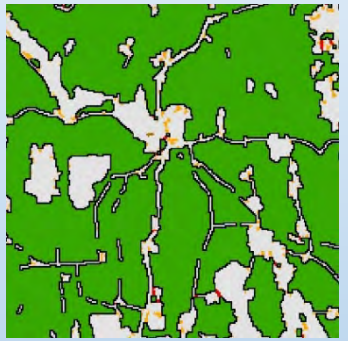
Interpreting Equivalent Area Index



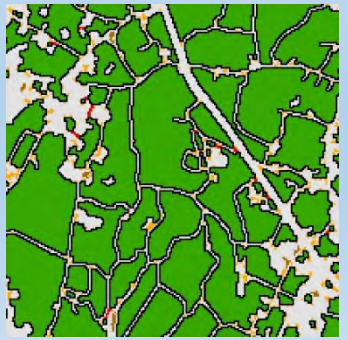




Landscape 823
P= 0.809
I = 0.767
Ir = 3.309

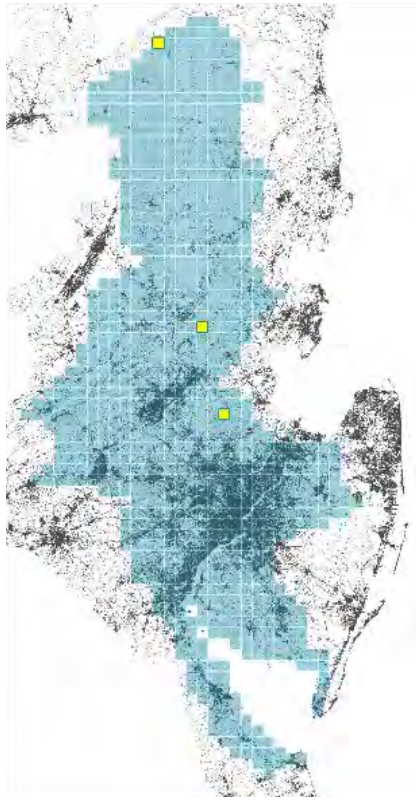


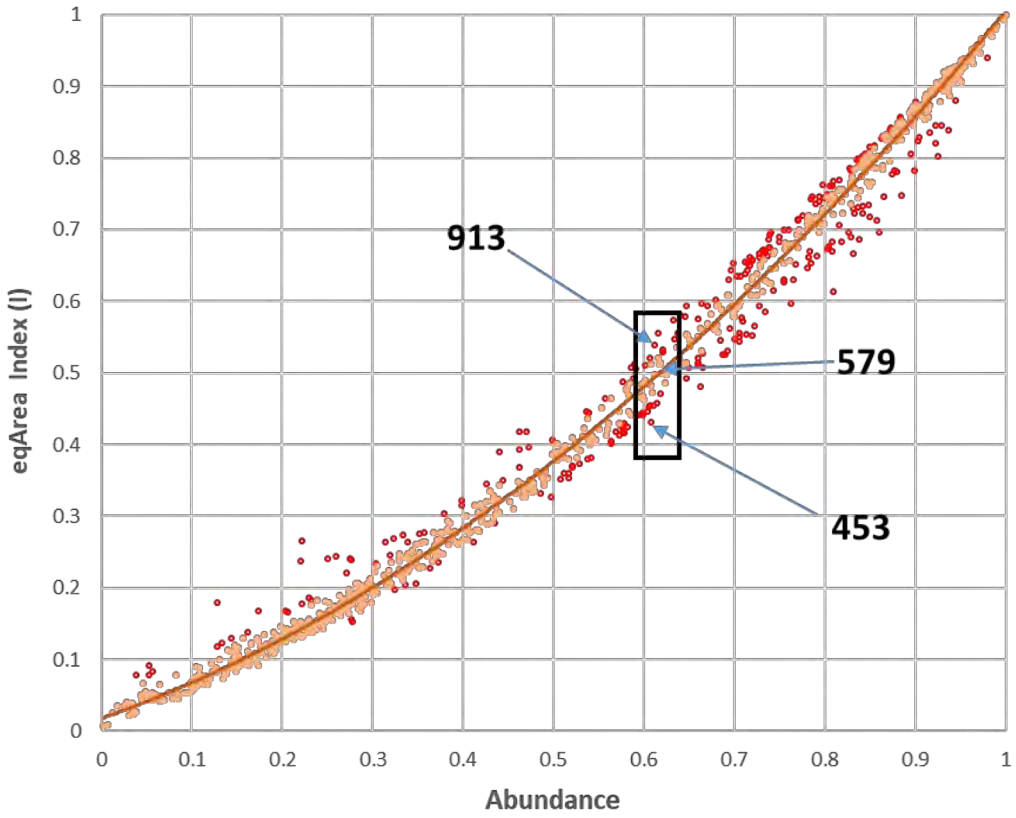
Landscape 796
P= 0.822
I = 0.749
Ir = -0.208

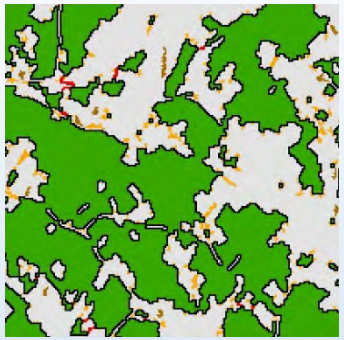


Landscape 379
P= 0.809
I = 0.614
Ir = -11.981

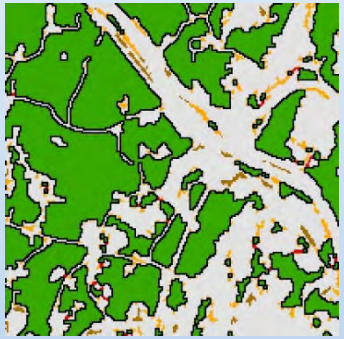
Interpreting Equivalent Area Index



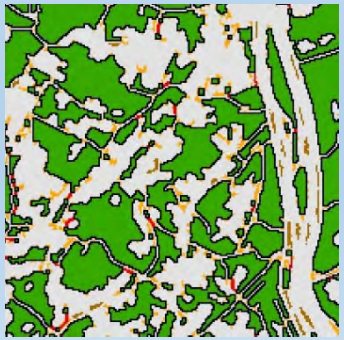




Landscape 913
P= 0.611
I = 0.534
Ir = 4.638

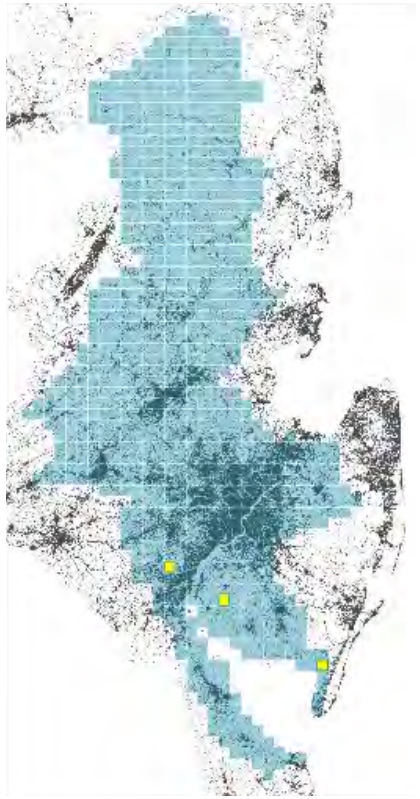


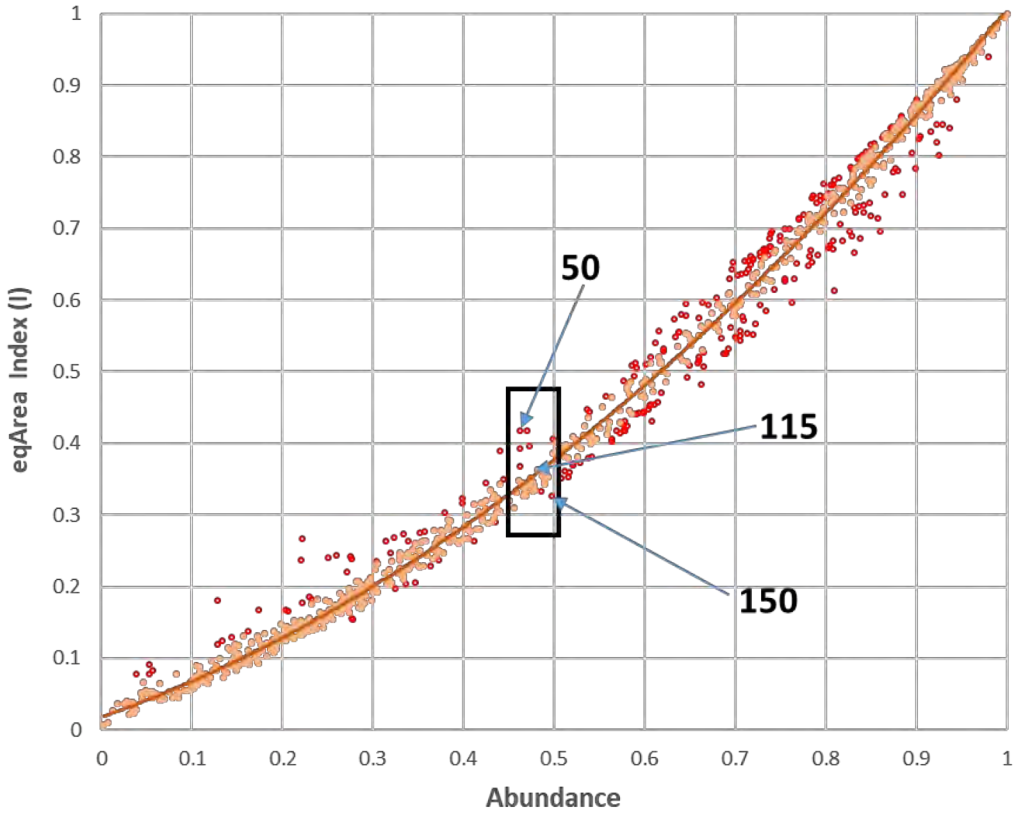
Landscape 579
P= 0.619
I = 0.500
Ir = -0.251

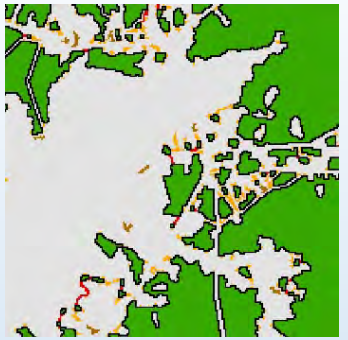


Landscape 453
P= 0.608
I = 0.431
Ir = -5.880

Interpreting Equivalent Area Index

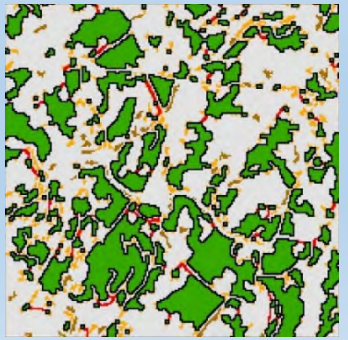






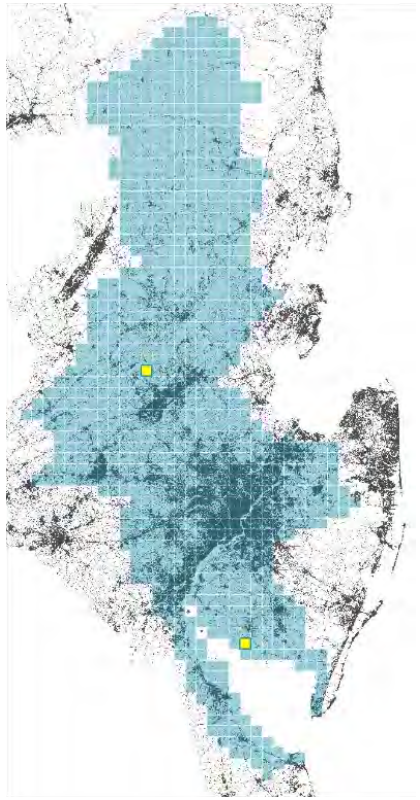
Landscape 50
P= 0.470
I = 0.418
Ir = 6.985

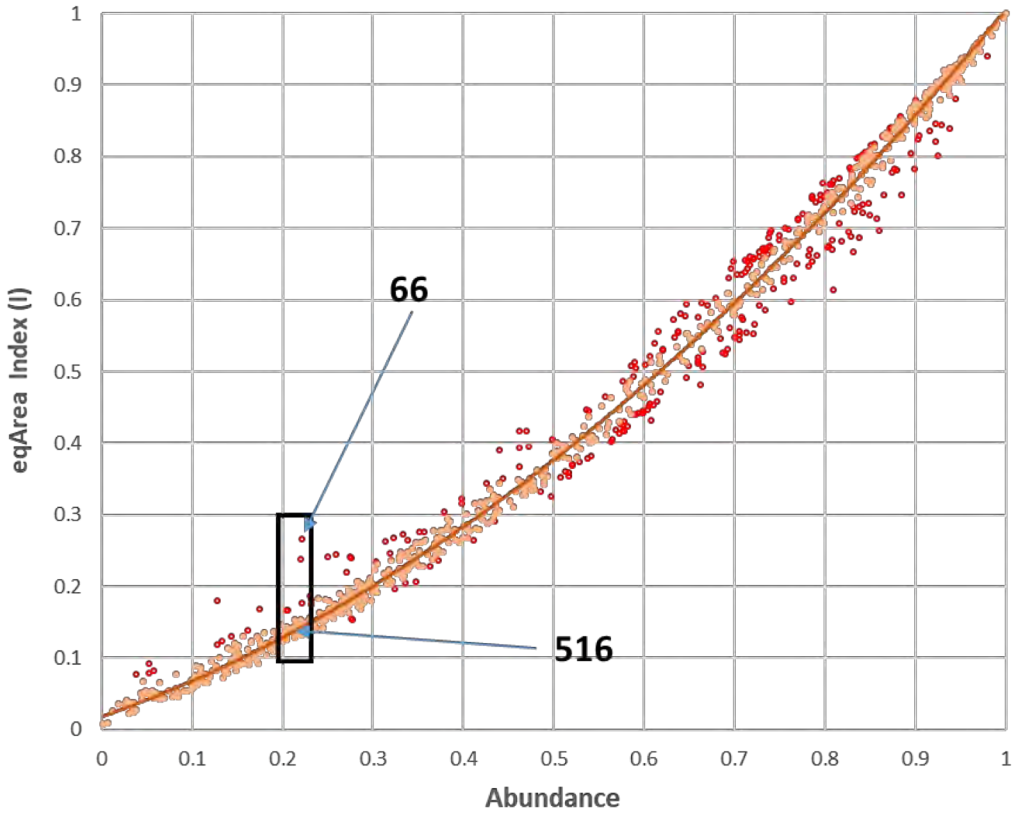
Landscape 115
P= 0.482
I = 0.363
Ir = 0.301



Landscape 150
P= 0.497
I = 0.326
Ir = -4.774

Interpreting Equivalent Area Index

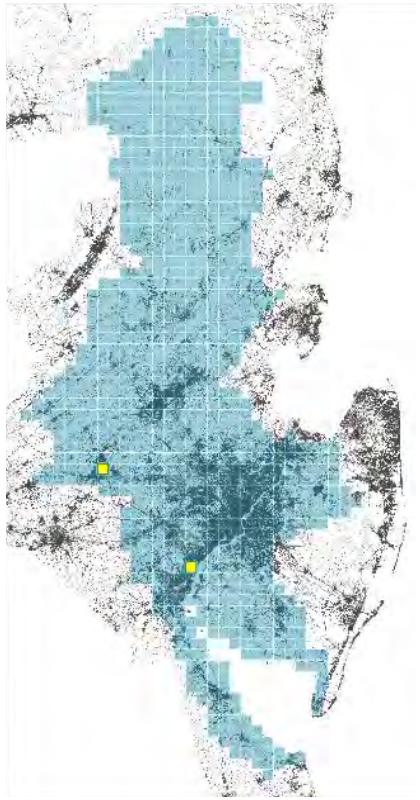


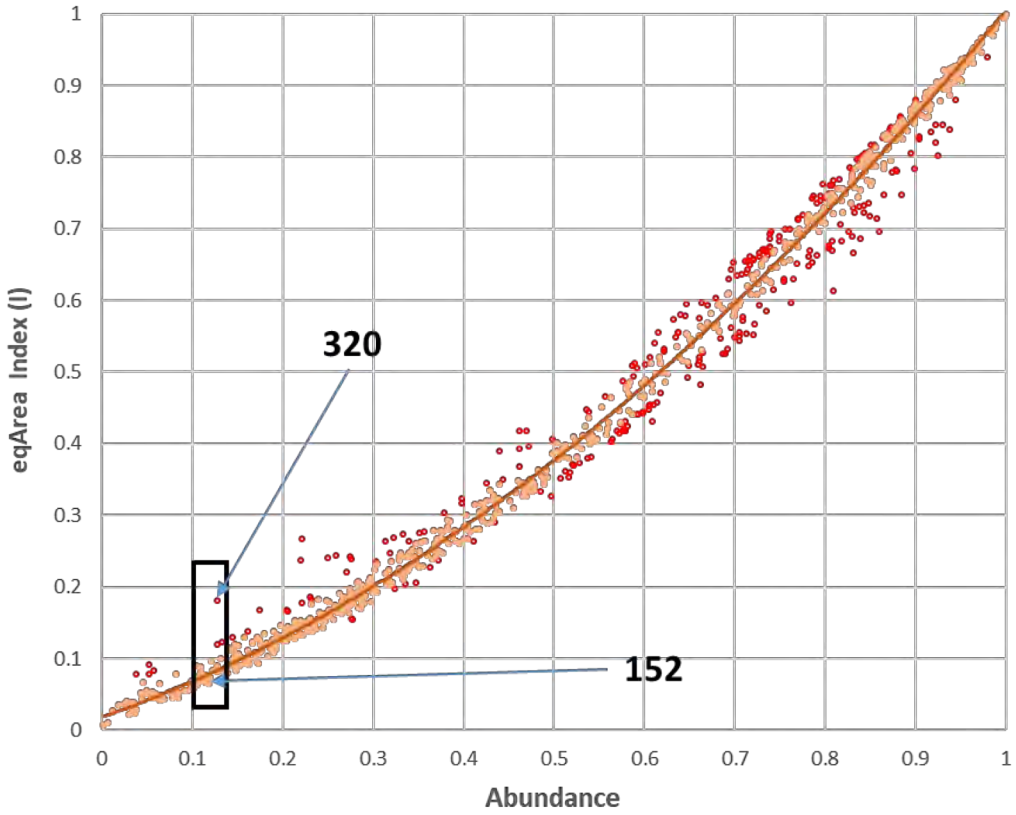


Landscape 66
P= 0.221
I = 0.177
Ir = 3.375

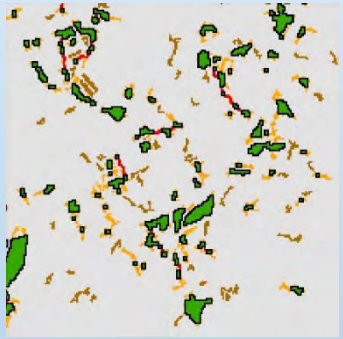
Landscape 516
P= 0.221
I = 0.148
Ir = 0.415

Interpreting Equivalent Area Index



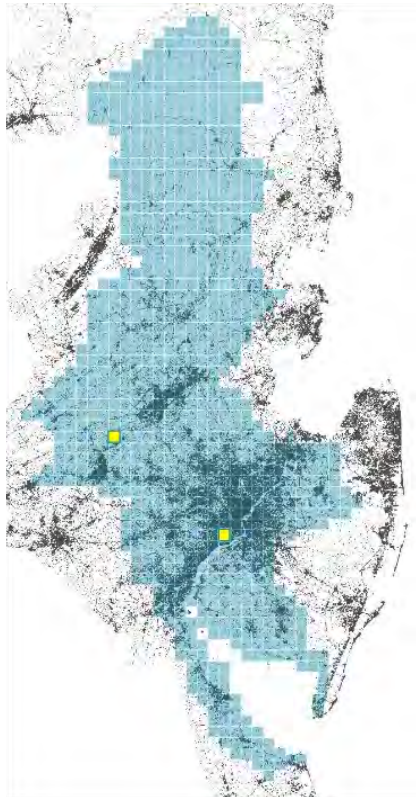


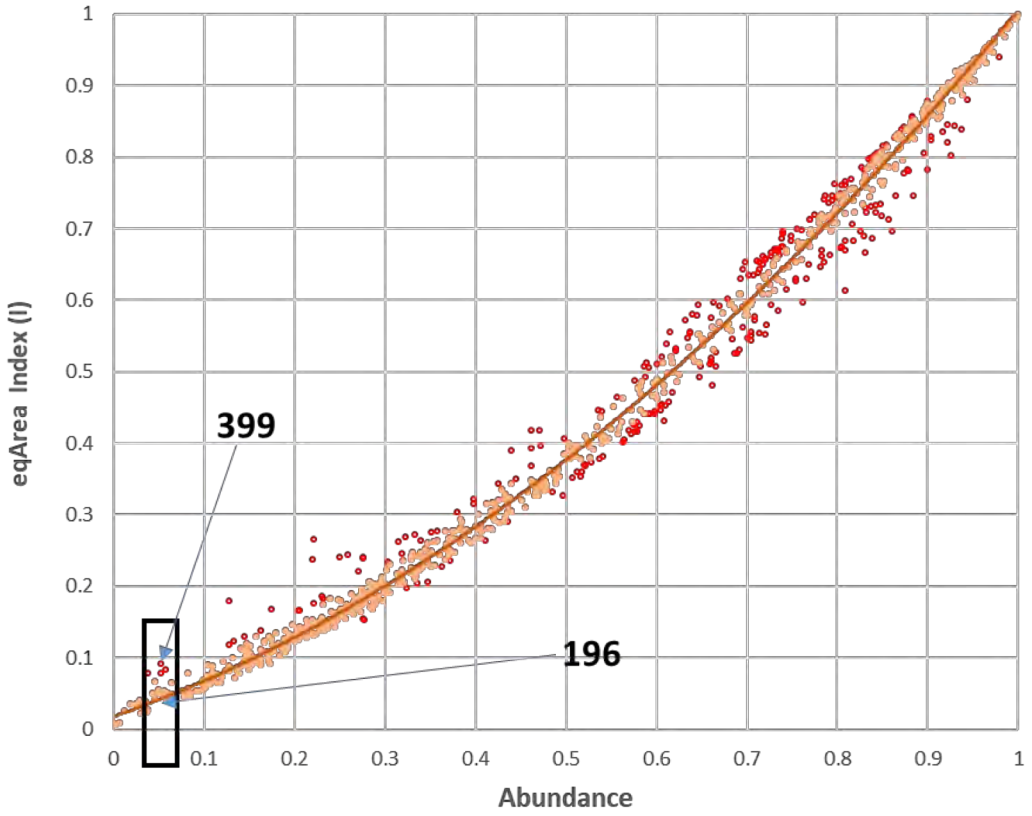
Landscape 320
P= 0.128
I = 0.180
Ir = 9.606



Landscape 152
P= 0.134
I = 0.073
Ir = -1.497

Interpreting Equivalent Area Index

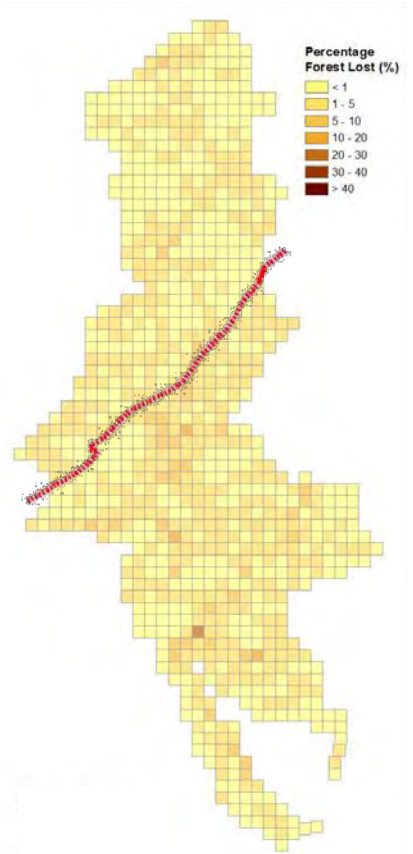




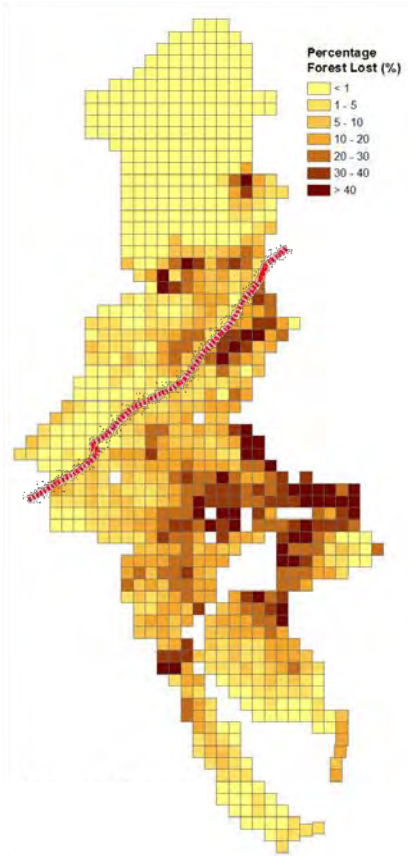
Landscape 399
P= 0.052
I = 0.078
Ir = 3.552

Landscape 196
P= 0.057
I = 0.045
Ir = -0.071

Forest Losses in 2100



Power Lines Scenario



Corridors Scenario 2100

Scenario	Total Losses		Highlands		Lowlands	
	ha	*%*	*ha*	*%*	*ha*	*%*
Corridors	36,390	7.4	36,390	3.2	96,761	14.4
Centers	9,667	3.2	9,667	0.9	48,552	7.2
Power lines	10,967	1 .2	10,967	1.0	10,278	1.5

Scenario	Total growth		Highlands		Lowlands	
	ha	*%*	*ha*	*%*	*ha*	*%*
Corridors	272,018	0.45	40,477	89.9	231,541	41.8
Centers	142,850	0.24	11,459	84.4	131,391	36.9
Power lines	50,629		14,090	77.8	36,539	28.1

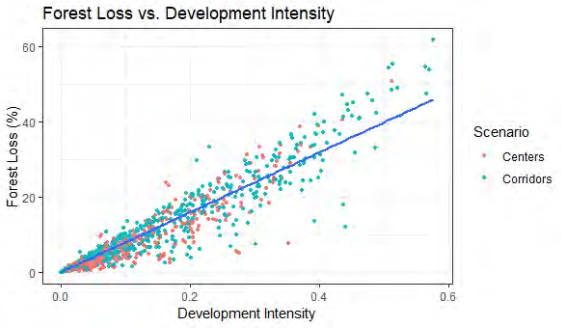
Annual rate in percentage

Forest Loss (%) ~ Development Intensity + Ir +0

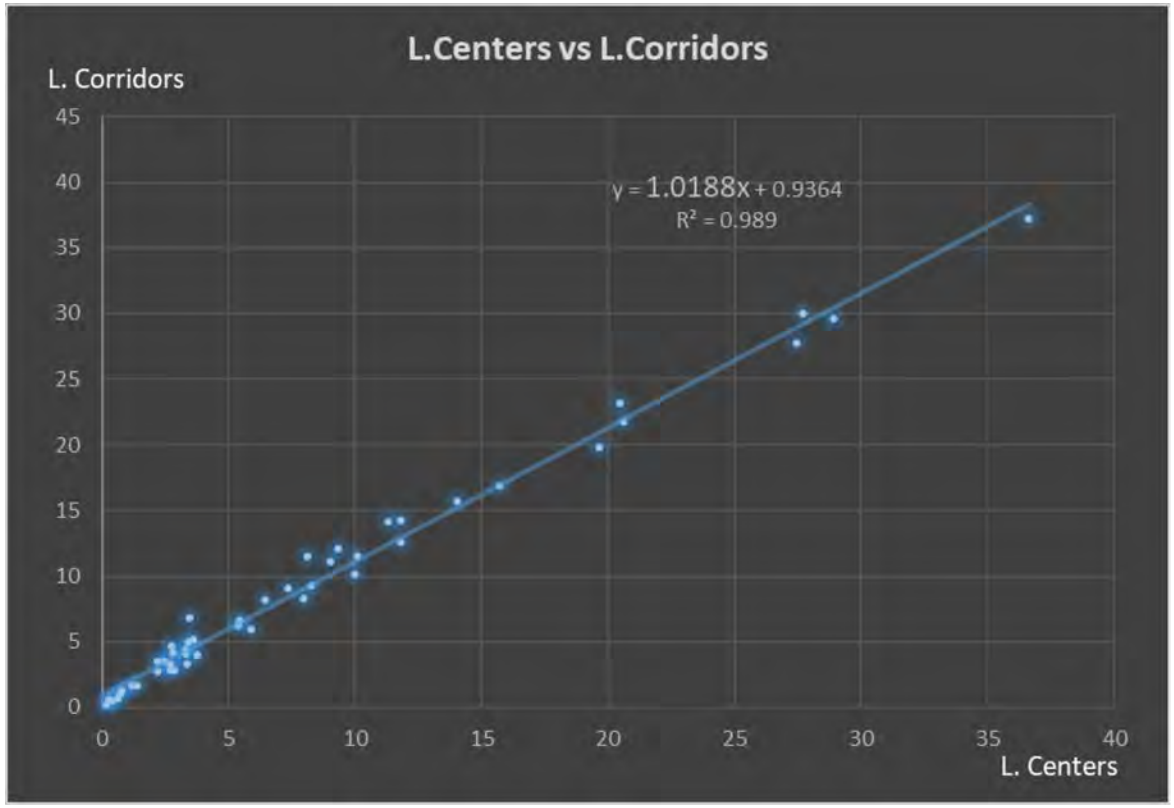
Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
Dev. Int.	48.520	1.417	34.231	< 2e-16 ***
Ir	-2.939	0.702	-4.187	5.03e-05 ***

Residual standard error: 3.446 on 137 degrees of freedom
Multiple R-squared: 0.8976, Adjusted R-squared: 0.8961
F-statistic: 600.7 on 2 and 137 DF, p-value: < 2.2e-16



Are Centers and Corridors scenarios equivalent?



- Comparison of forest lost generated by both scenarios at the same development intensity.
- Differences are statistically significant, but are close to 1%.
- Differences remain consistent along the loss gradient.

  - Paired t-test

    $\bar{d} = 1.092\ \%$ $p\text{-}val = 1.97\text{e-}10$

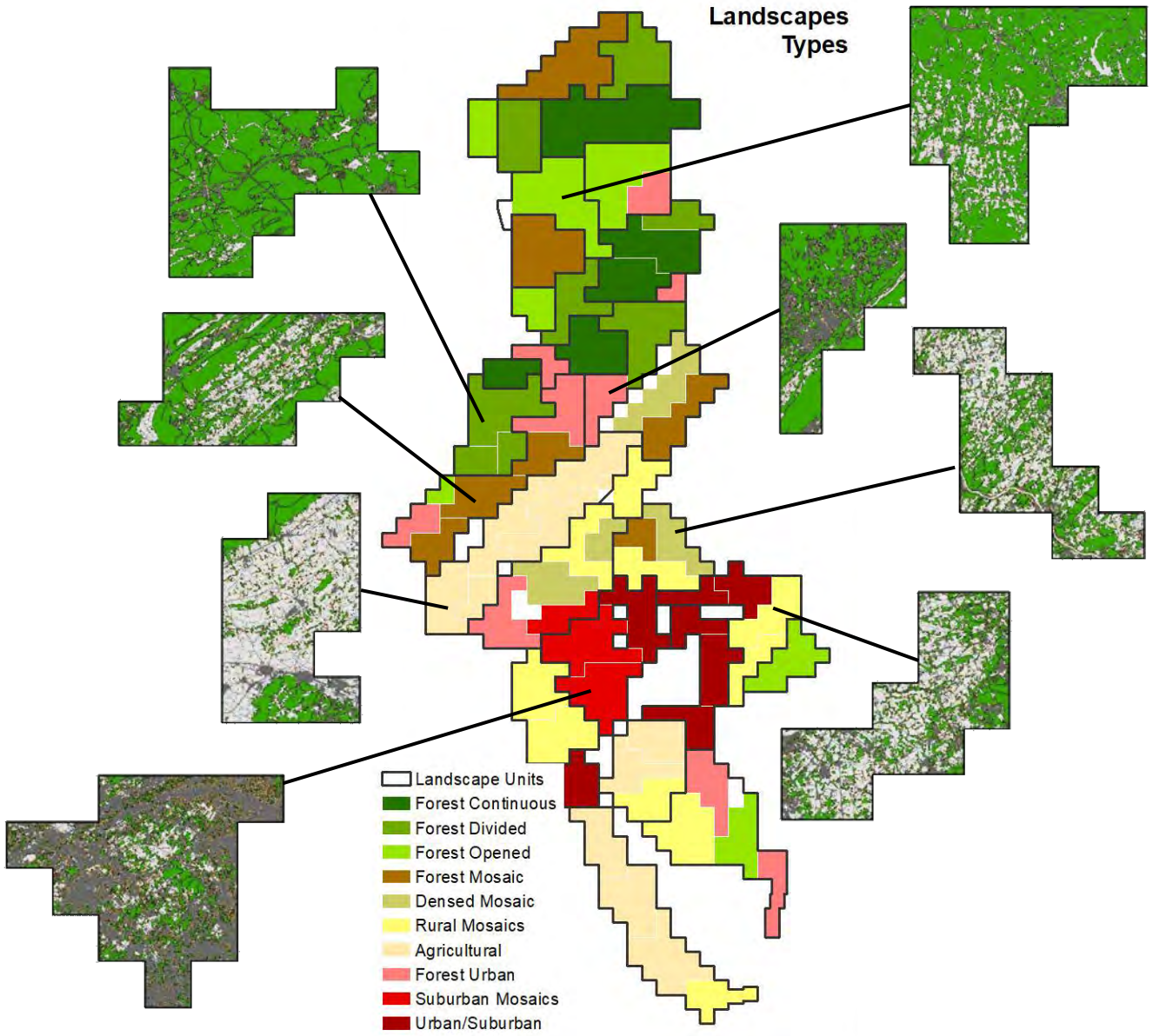
  - Regression Analysis

	Estimate	Std. Error	t-value	Pr(>|t|)
Intercept	0.936	0.191	4.894	1.31e-5 ***
Slope	1.019	0.016	63.488 (1)	< 2e-16 ***
			1.1704 (2)	0.247

(1) H0: Slope = 0 H1: slope ≠ 0
(2) H0: Slope = 1 H1: slope > 1

$R^2_{adj} = 0.9962$

Classifying Landscapes



Landscapes
6 x6 km

- Landscape composition and configuration
- PCA & Regional Cluster

Landscape Units

- Urban Presence & growth
- Automatic/Manual

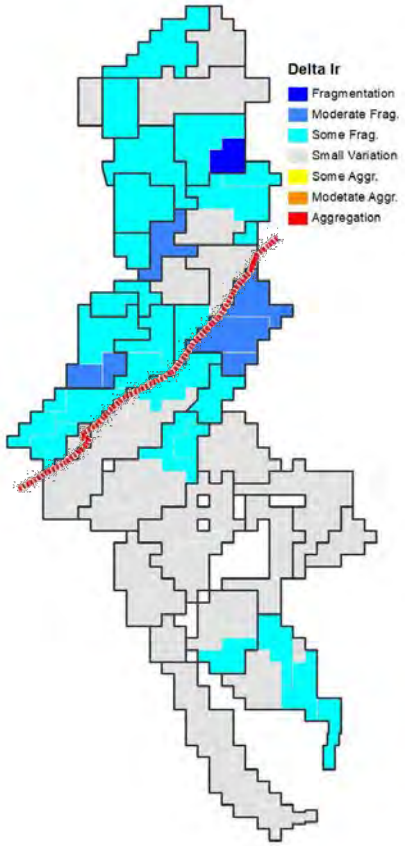
Landscape Subunits

- Forest, Urban, Ir

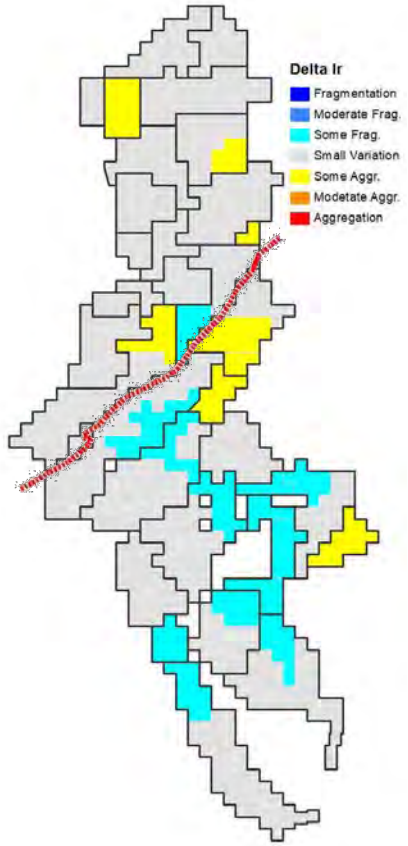
Landscape Types

Forest presence		Urban		
		Not frequent		Frequent
Infrequent	≤ 30%	Agricultural		Suburban
Frequent	31% - 43%	Rural Mosaic		Sub. Mosaic
Abundant	44% - 60%	Dense Mosaic		Forest-Urban
Very Abundant	61% - 75%	Forest Mosaic	Aggregated	
Deeply Forested	76% - 89%	Forest Divided	Opened	
	≥ 90%	Forest Continuous		

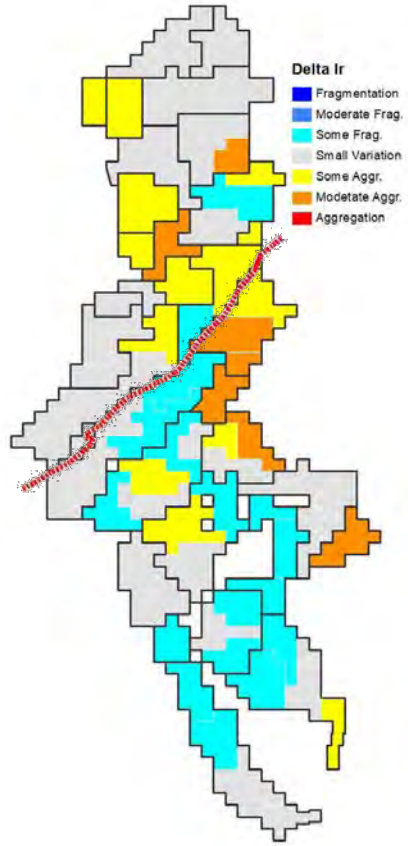
Evolution of Fragmentation. Change of *Ir* Index



Power Lines Scenario



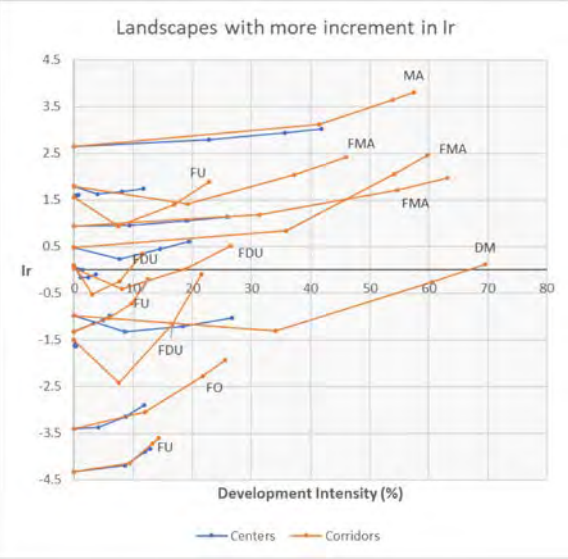
Centers Scenario 2100

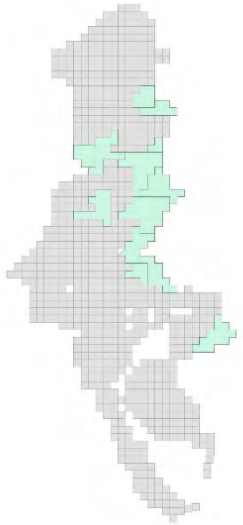


Corridors Scenario 2100

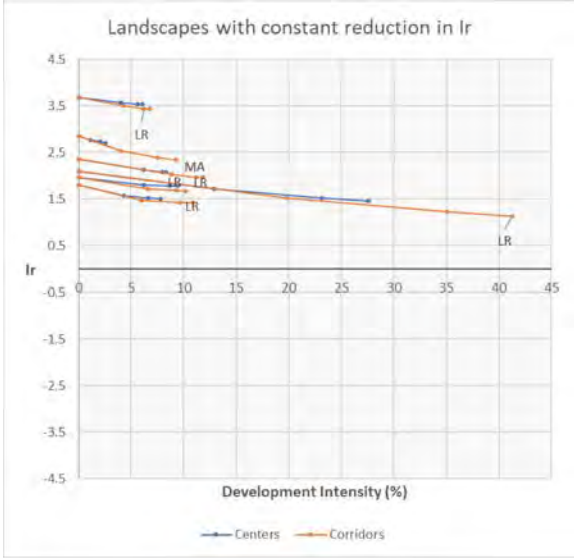
- Negative differences of ***Ir*** index over time represent transitions towards more fragmented situations.
- Energy transportation infrastructure has more capacity to divide big patches, as a result it produces more fragmented landscapes with less losses.
- Urban development shows more variety of direction of the change, that reflects the variability of factors and process involved.
  - ✓ Isolation
  - ✓ Discriminant removal
  - ✓ Edge density
  - ✓ Etc…
- Landscapes with high development intensity trend to reduce the fragmentation index.
- Urban development proportionally affects more habitat of less quality.

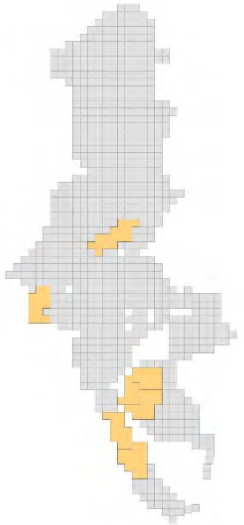
Trajectories of Ir index when Development intensity increase in time



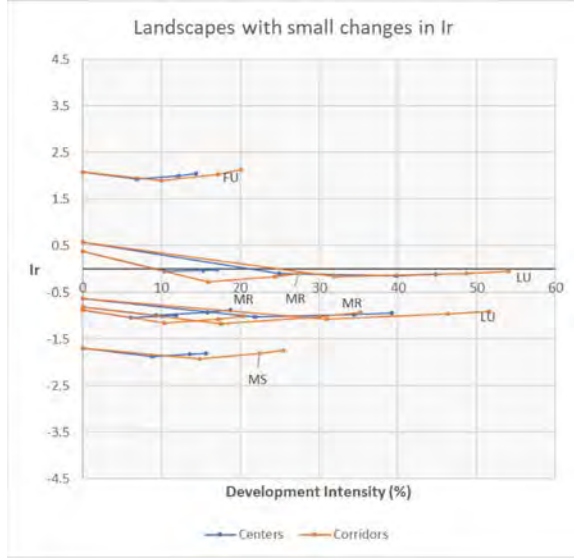


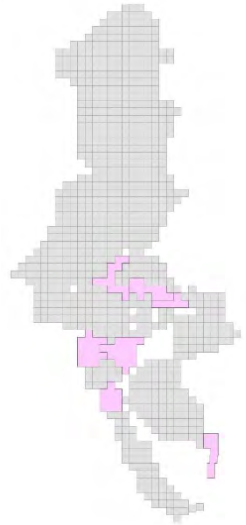
- Forested landscapes or dense mosaics, usually with more than 60% of forest.
- Development intensity is high or interphase forest-urban





- Agricultural areas.
- Historical process

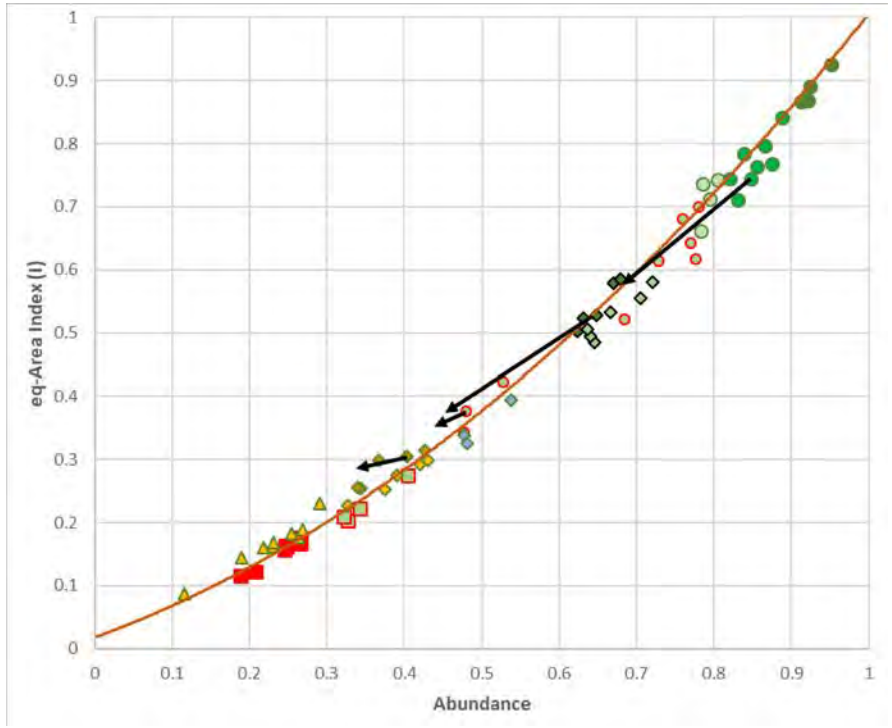




- Landscapes with important urban presence.
- Forest Mosaics (<50%)
- Simple Topography

Conclusions

- Many factors can influence urban growth fragmentation pattern: forest abundance, topography and conservation areas and there is no single recipe.
- Initial conditions of habitat pattern may influence the fragmentation process. For example, aggregated patterns may prevent slightly habitat loss, however the influence can be shaded by other circunstances.
- Principal divergences of the historical pattern are raised when Urbanization occurs in forest landscapes or rural mosaics with large amount of forest, instead to have a agricultural transition.
- This is relatively new and is expected to increase in the future when metropolitan suburbs reach forest landscapes.
- The new pattern will have ecological implications. Less number of patches, some of then relatively bigger but with more simple shapes.
- We have to consider the new matrix will be less suitable and perturbations will increase. Also that it is a permanent matrix, there is no backward.
- Connectivity probably will be an issue in some areas, but this is a subject for a future chapter.



Urban growth in forested landscapes maybe will create new paths in the fragmentation process transforming the shape of the curve.

THANK YOU!

Contact Us!

Alfonso Yáñez Morillo

Research Analyst
Center for Land Use and Sustainability
ayanezmorillo@ship.edu

Claire Jantz, Ph.D.

CLUS Director & Professor
Department of Geography-Earth Science
cajant@ship.edu

Antonia Price

Project Manager
Center for Land Use and Sustainability
afprice@ship.edu

DELAWARE RIVER BASIN
Land Use Dynamics
SHIPPENSBURG UNIVERSITY

www.drbproject.org

www.centerforlanduse.org

Center for Land Use and Sustainability
SHIPPENSBURG UNIVERSITY

@ShipCLUS **/ShipCLUS**

- FINAL