Appalachian STATE UNIVERSITY

LAND USE AND LAND COVER AS A TEMPLATE FOR TICK POPULATIONS

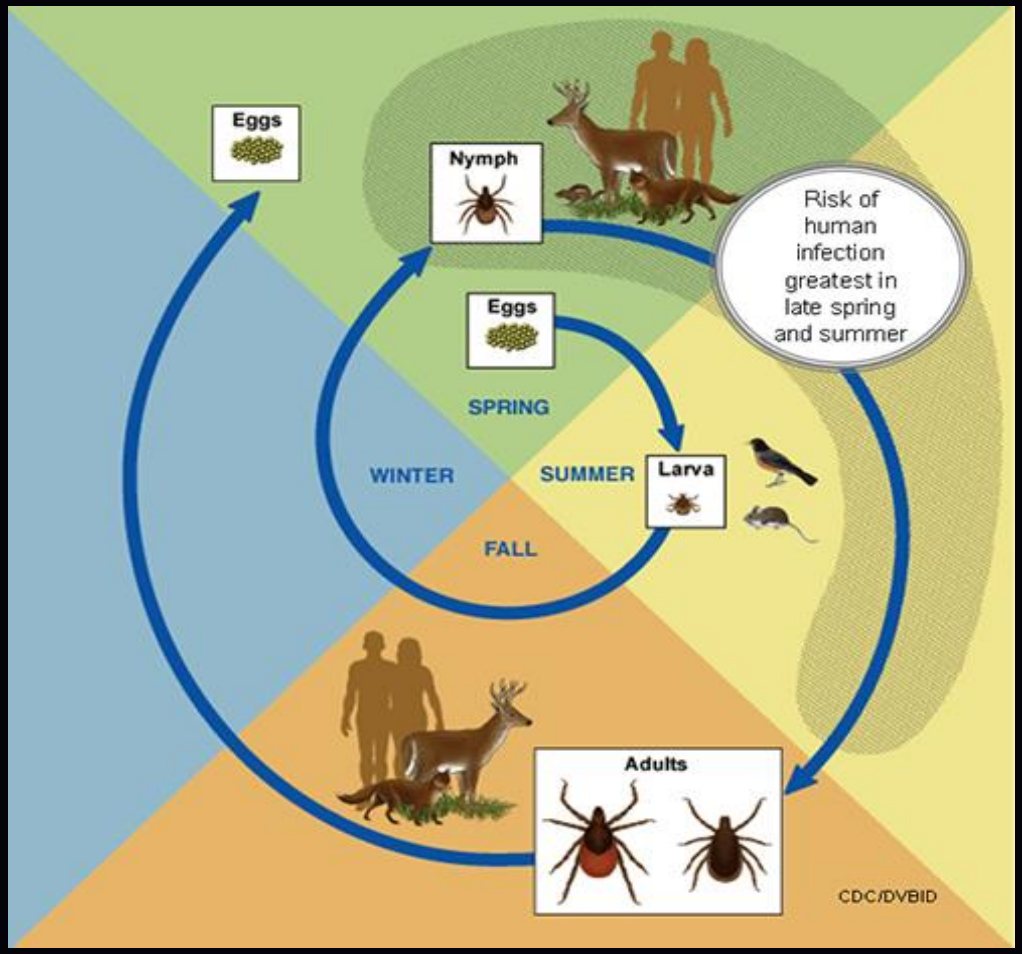
Steve Seagle
(seaglesw@appstate.edu)

Department of Biology
Appalachian State University

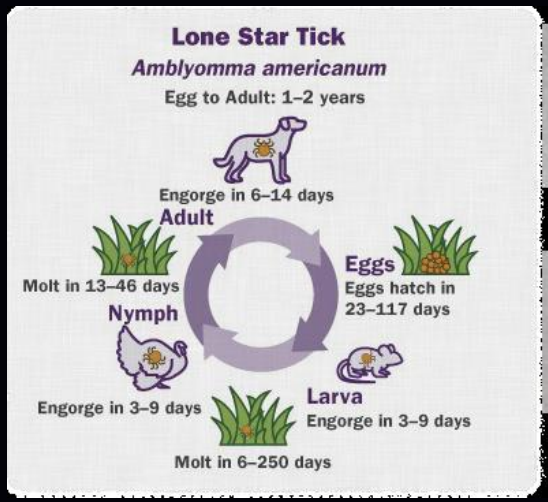
http://hardinmd.lib.uiowa.edu/cdc/ticks.html

TICK LIFE CYCLES

- Multiple blood meals before maturity
- Most of life cycle is spent off of hosts*
- Host species vary notably*



http://www.cdc.gov/lyme/transmission/blacklegged.html



TICK HOST SPECIES

Vary greatly in body size, home range, and landscape use/perception

Home Range
Up to 2010 ac
Up to 813 ha

LANDSCAPE

Home Range
20 – 75 ac
8 – 30 ha

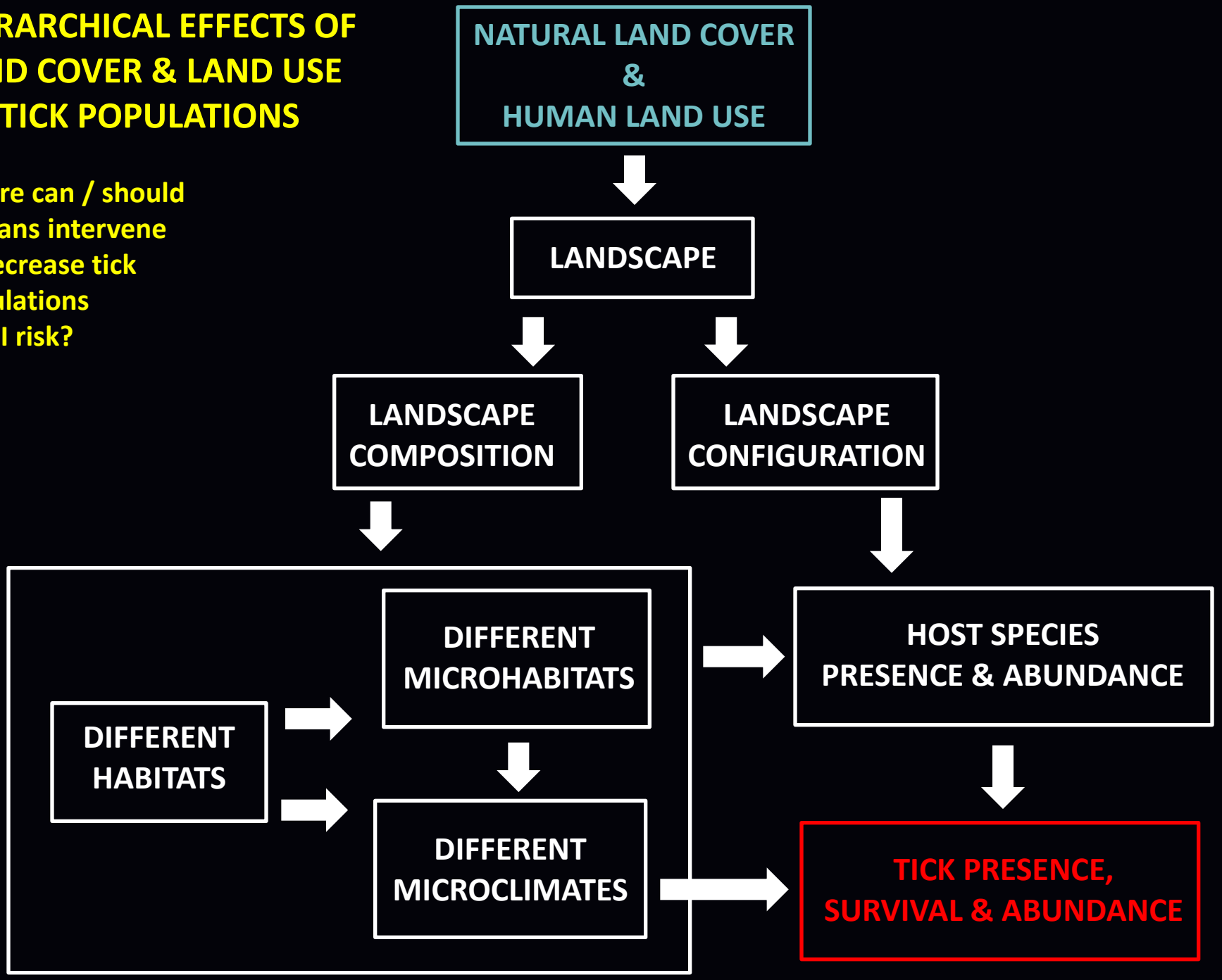
SMALL LANDSCAPE OR HABITAT

Home Range
0.5 – 1.5 ac
0.2 – 0.6 ha

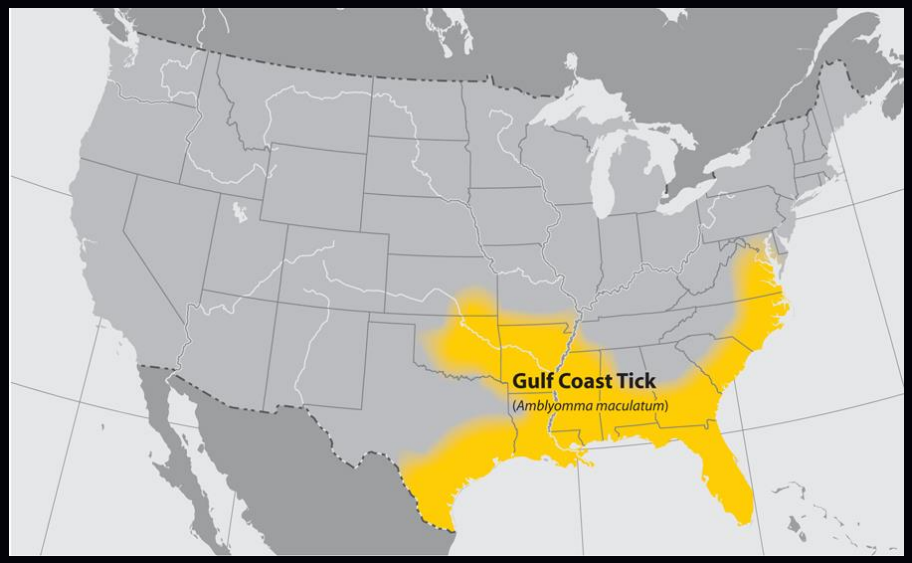
MICROHABITAT

HIERARCHICAL EFFECTS OF LAND COVER & LAND USE ON TICK POPULATIONS

Where can / should humans intervene to decrease tick populations & TBI risk?



RANGE MAPS FOR THE MAJOR TICK-BORNE DISEASE VECTORS FOUND IN NC

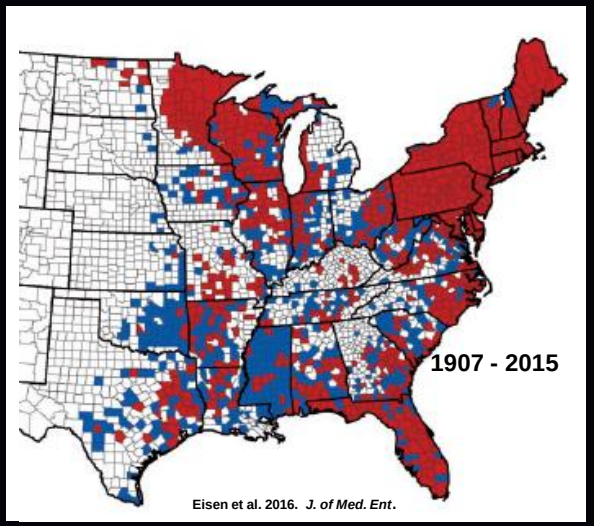


https://www.cdc.gov/ticks/geographic_distribution.html

TWO QUESTIONS FOR ANALYZING TICK-LAND USE RELATIONSHIPS

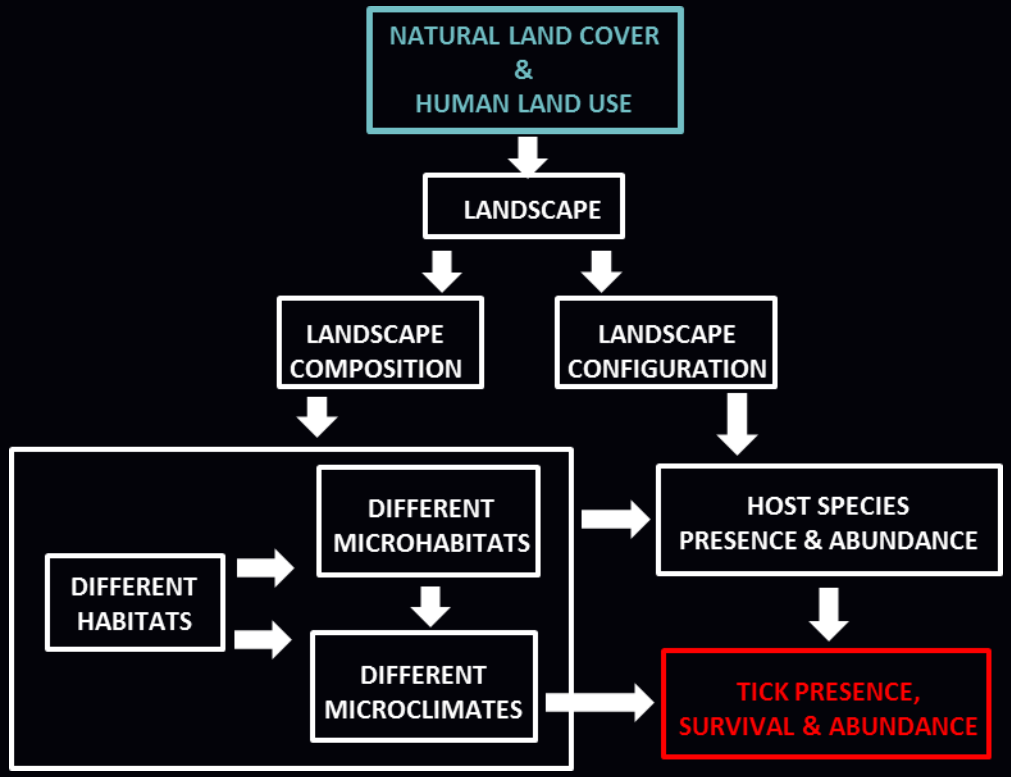
1. **At what spatial resolution do you want to understand relationships?**
   Range, County, Habitat Type, Microhabitat

Blacklegged Tick Distribution
Red – Established; Blue - Reported



2. **Can human case incidence be used as a surrogate for tick occurrence/density?**

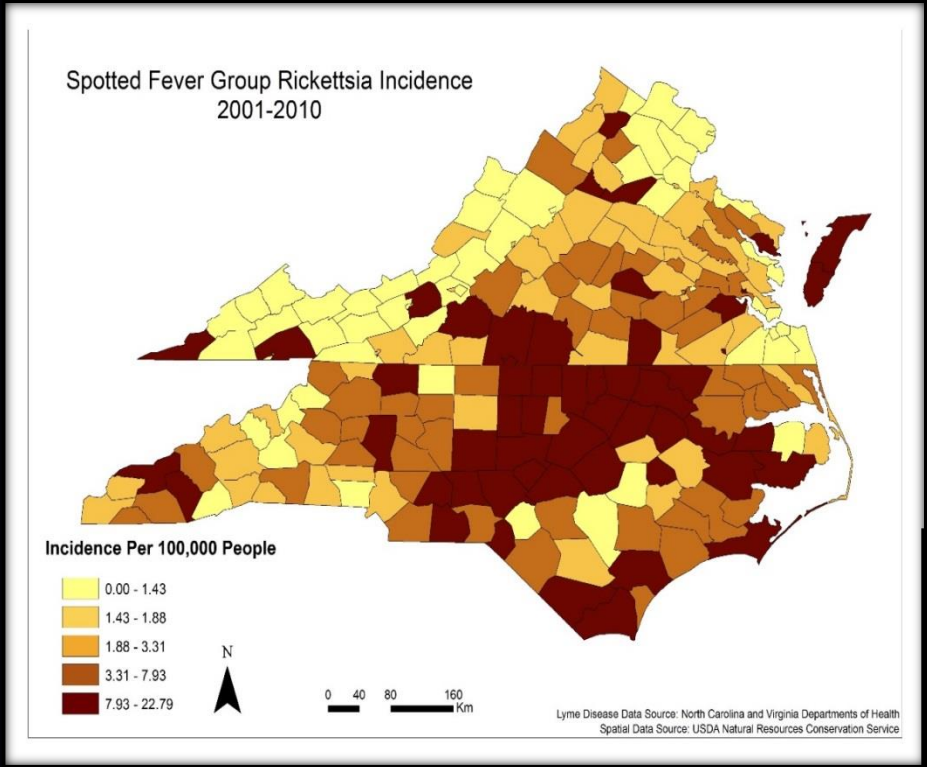
LANDSCAPE AND CLIMATE PREDICTORS OF SFGR AND LYME DISEASE INCIDENCE IN NORTH CAROLINA AND VIRGINIA

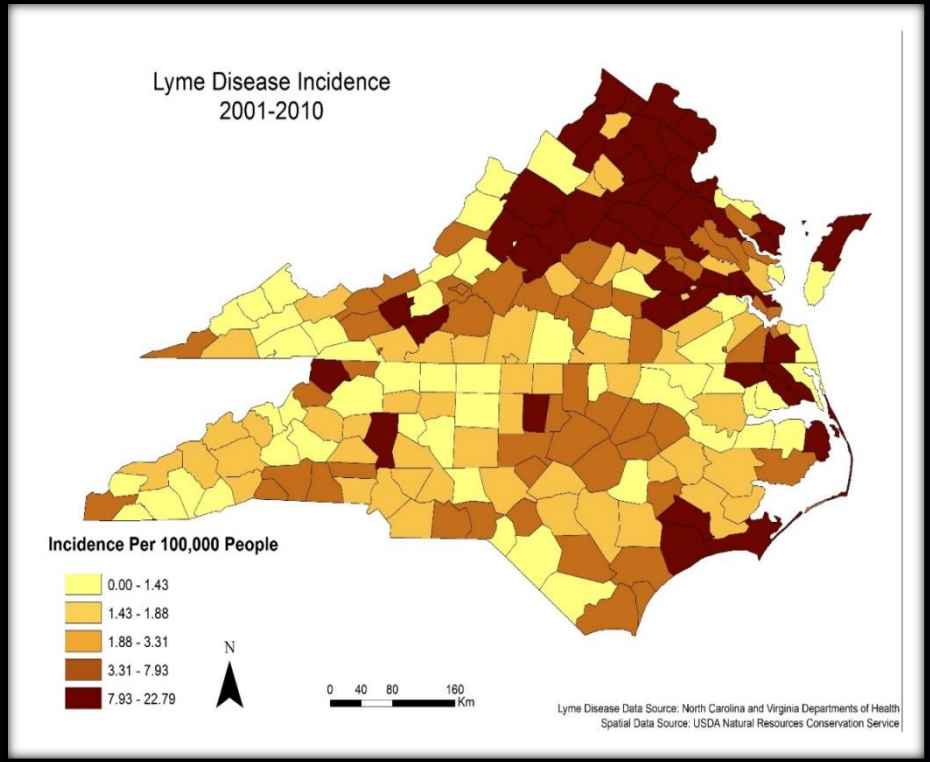


Hierarchy Level: Landscape Composition & Configuration, Plus Climate
Resolution: County
Response Variable: Human Case Incidence

Spotted Fever Group Rickettsia And Lyme Disease Incidence

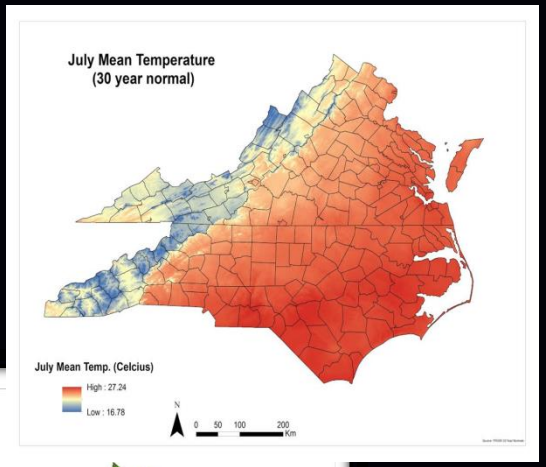
NC & VA
2001 - 2010

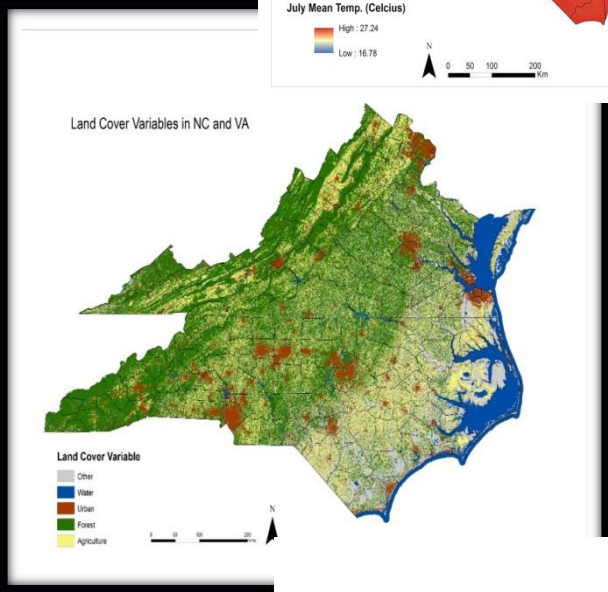


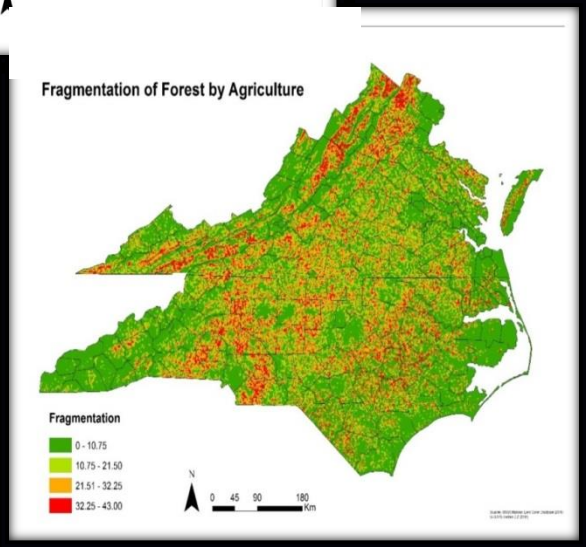


DISEASE INCIDENCE

Human case data for RMSF and Lyme disease were collected from North Carolina and Virginia Department of Health websites for 2001 to 2010. Annual disease incidence (number of cases / 100,000 people) was calculated and averaged for each county.







Variables Used To Predict Disease Incidence (All aggregated to the county level)

Climate Variables

- 1987 – 2010 data from the PRISM model
- 800 m spatial resolution
- Jan and July
  - Temperature: Mean, Max, Min
  - Precipitation: Mean
  - Relative Humidity
  - Dew point
  - Vapor pressure & saturated vapor pressure

Land Use / Land Cover

- 2011 coverage of NC & VA from the NLCD
- Percent cover for forest, agriculture, urban, water

Forest Fragmentation

- 30 m spatial resolution
- Forest fragmentation by agriculture
- Forest fragmentation by urban
- Contagion of habitat types
- Calculated by edge type percent in a 5x5 moving window

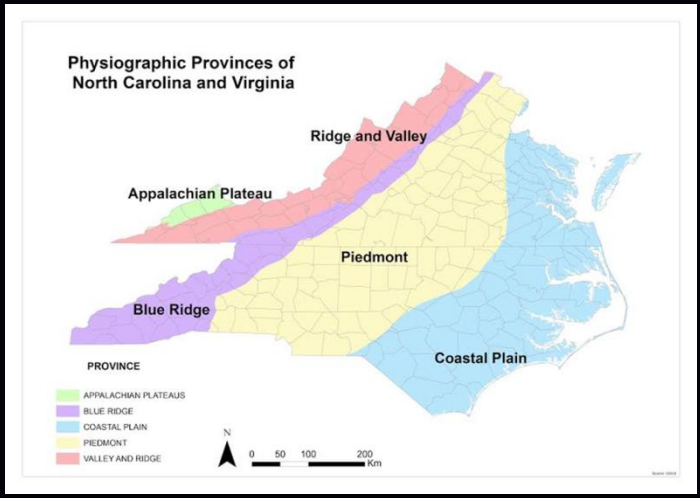
Statistical Analysis

1. Principal components analysis to reduce predictor variable number
   (Results in PCs that are simply a linear combination of the original variables)

2. Correlation analysis to interpret PCs in terms of original variables

3. Multiple regression of RMSF and LD incidence on PCs that explain the greatest variation in the land use and climate variables

   All VA and NC counties combined ("global")
   Counties by physiographic province



4. Geographically weighted regression, which groups counties independent of physiographic province for doing regression

Results: Principal Components Analysis

Interpretation of Principal Components

PC	Variance	Environmental Gradient		
1	48	High Jan & July Temp High Jan & July VP	⟷	Low Jan & July Temp Low Jan & July VP
2	17	High Forest Frag by Ag & Urb	⟷	Lower Forest Frag by Ag & Urb
3	12	Var. in Frag by Ag & Urb	⟷	Low Var. in Frag by Ag & Urb
4	8	High Forest Cover & Clumped Low Urban Cover	⟷	Low Forest Cover & Un-clumped High Urban Cover

Thus landscape composition, landscape configuration & climate are all important for characterizing biological and physical variation among NC and VA counties

Are these principal components related to disease incidence?

Comparing Global And Physiographic Province Regression Models

Dependent Variable: Disease Incidence

Independent Variables: Principal Components 1- 4

	N	P	R^2	CV
Global				
Lyme Disease	218	<.0001	.21	203.26
Spotted Fever Rickettsia	218	<.0001	.27	102.57
Coastal Plain				
Lyme Disease	75	.01	.16	198.28
Spotted Fever Rickettsia	75	.05	.12	95.79
Piedmont				
Lyme Disease	79	<.0001	.49	178.38
Spotted Fever Rickettsia	79	<.0001	.39	86.96
Ridge and Valley				
Lyme Disease	28	<.0001	.69	106.07
Spotted Fever Rickettsia	28	.07	.30	113.16
Blue Ridge				
Lyme Disease	32	.09	.25	215.96
Spotted Fever Rickettsia	32	.75	.07	88.95

Comparing Global And Geographically Weighted Regression Models

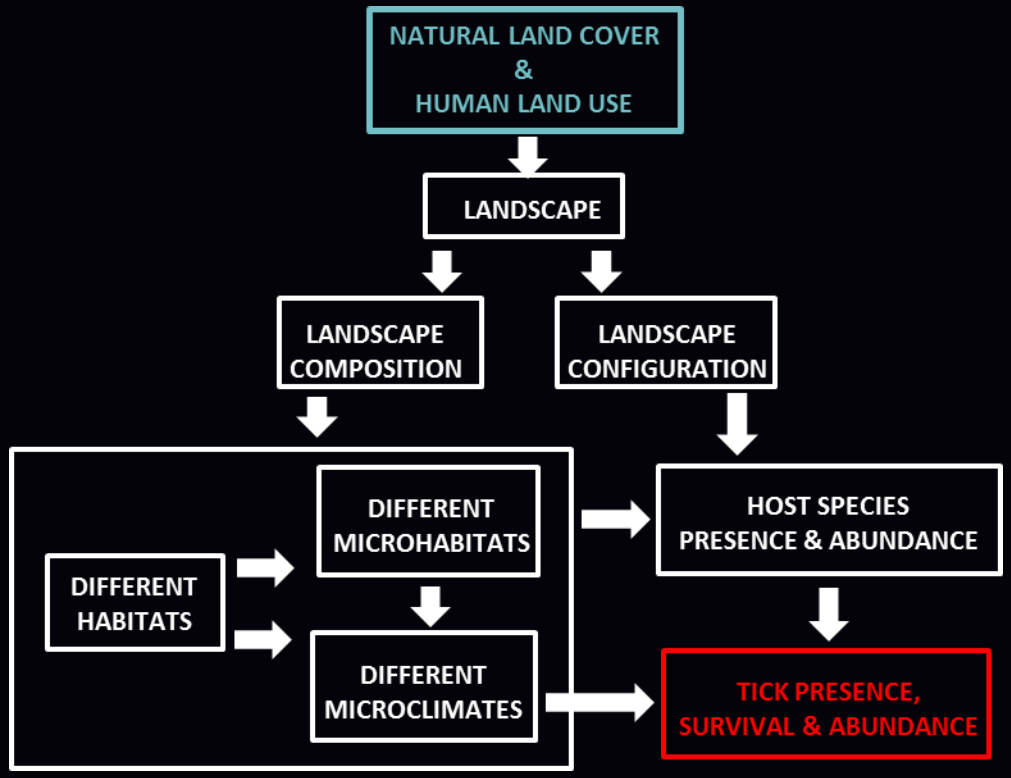
Dependent Variable: Disease Incidence

Independent Variables: Principal Components 1- 4

	N	R^2	CV	AICc
Lyme Disease				
Global	218	.21	63.31	1518.52
Geographically Weighted	218	.76	34.34	1349.35
Spotted Fever Rickettsia				
Global	218	.27	12.33	1168.71
Geographically Weighted	218	.56	9.83	1124.49

Summary: Climate, Landscape Composition & Landscape Configuration are all significantly correlated with TBI incidence

PREDICTING THE EMERGENCE OF LYME DISEASE IN THE BLUE RIDGE AND RIDGE-AND-VALLEY OF NORTH CAROLINA AND VIRGINIA



Hierarchy Level: Landscape Composition & Configuration, Plus Climate

Resolution: 1 km^2 (Sub-County)

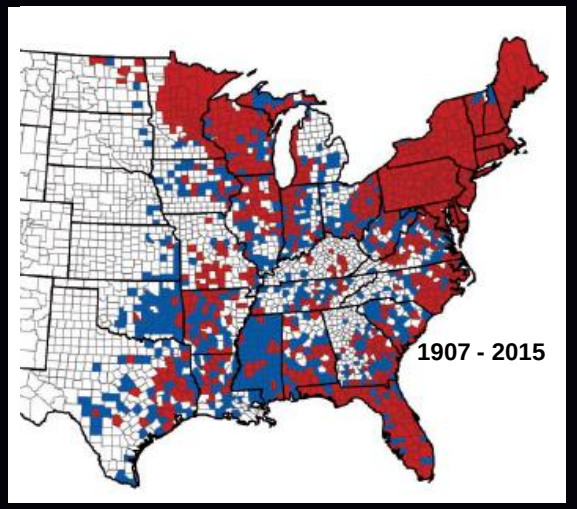
Response Variable: Similarity to locations with high Lyme case incidence

Blacklegged Tick & Lyme Disease Spread

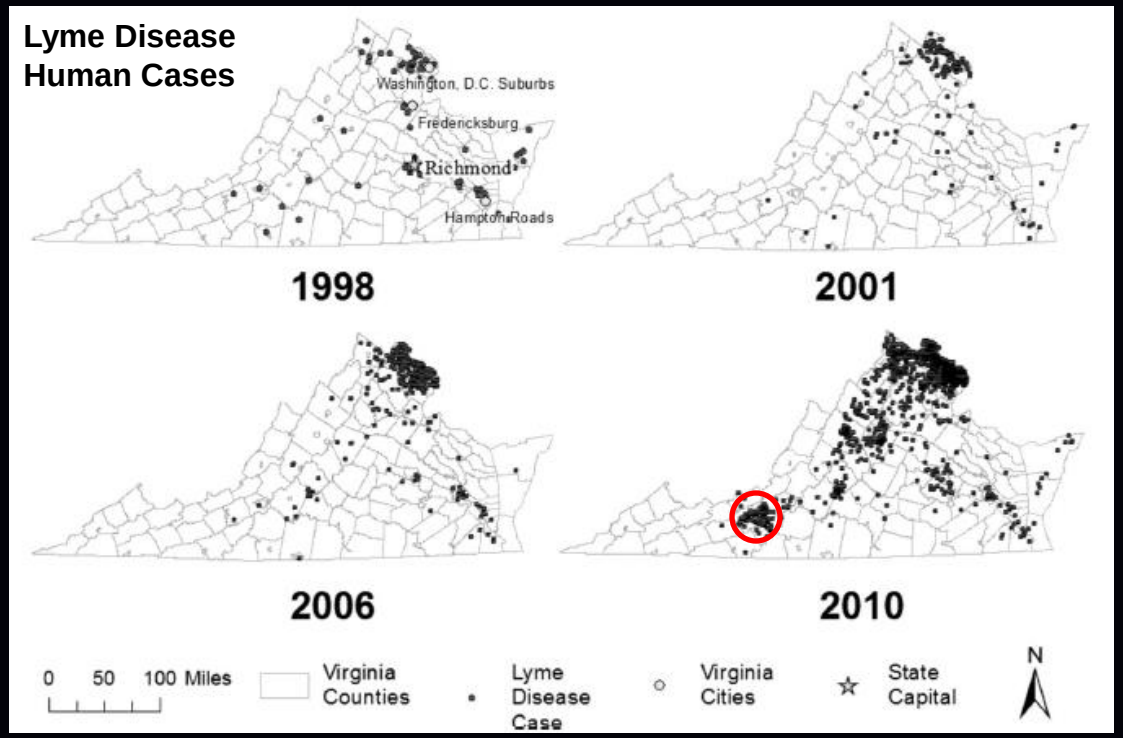
Most U.S. cases in Northeast and Upper Midwest
Even though *I. scapularis* occurs over much of eastern U.S.

Over the last decade successive clusters of human cases have expanded southward along the Blue Ridge Mountains

Blacklegged Tick Distribution
Red – Established; Blue - Reported



Eisen et al. 2016. *J. of Med. Ent.*



Seukep et al. 2015. *EcoHealth*

SW VA: Pulaski, Montgomery & Floyd Co.

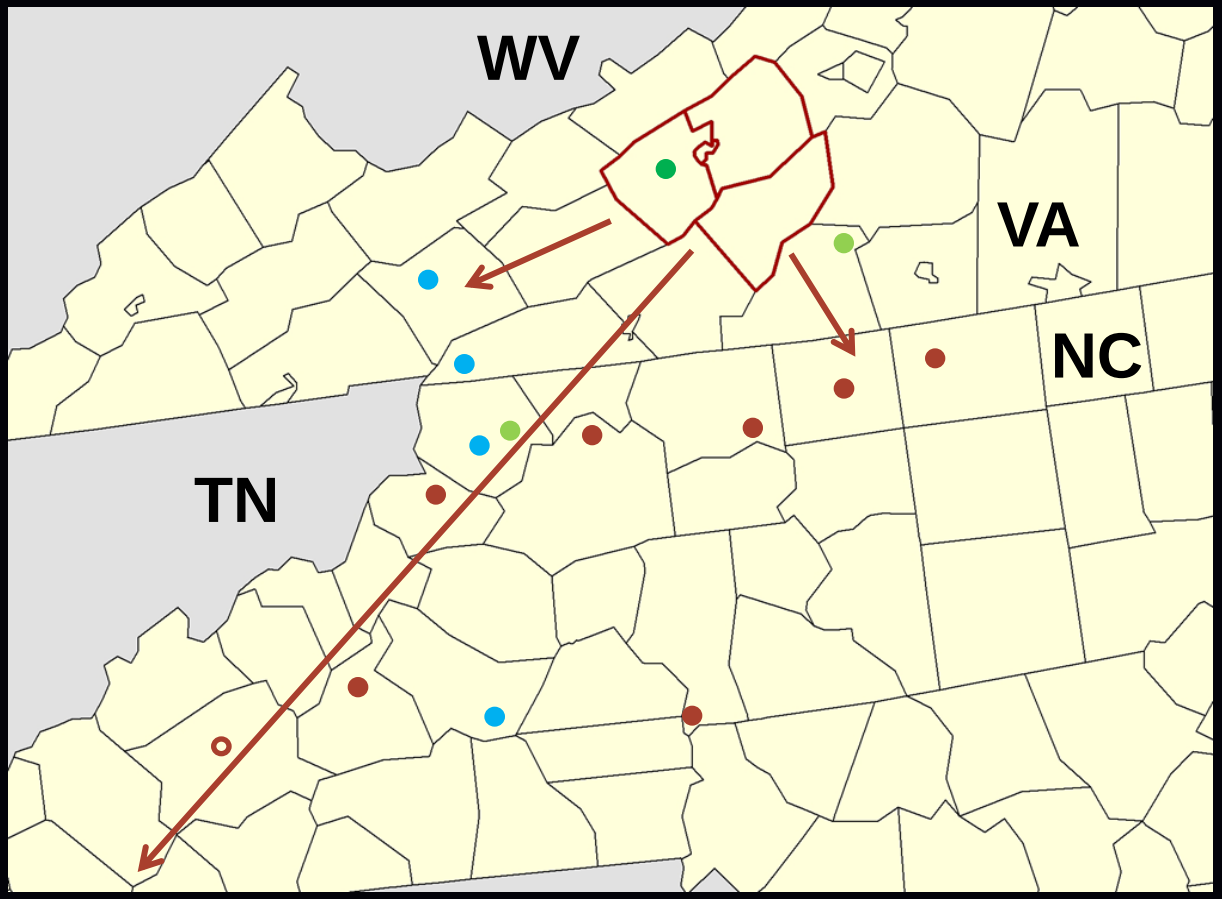
BLT considered established
BLT sampled personally
BLT carries Lyme disease bacterium*
Cluster of human cases

* Herrin et al. 2014. *Vector-Borne And Zoonotic Diseases*

GOALS: Explore the presence, density and infection status of Blacklegged ticks in western NC

Develop testable hypotheses for the locations of Blacklegged tick populations in northwest NC

Predict the regional emergence of Lyme disease



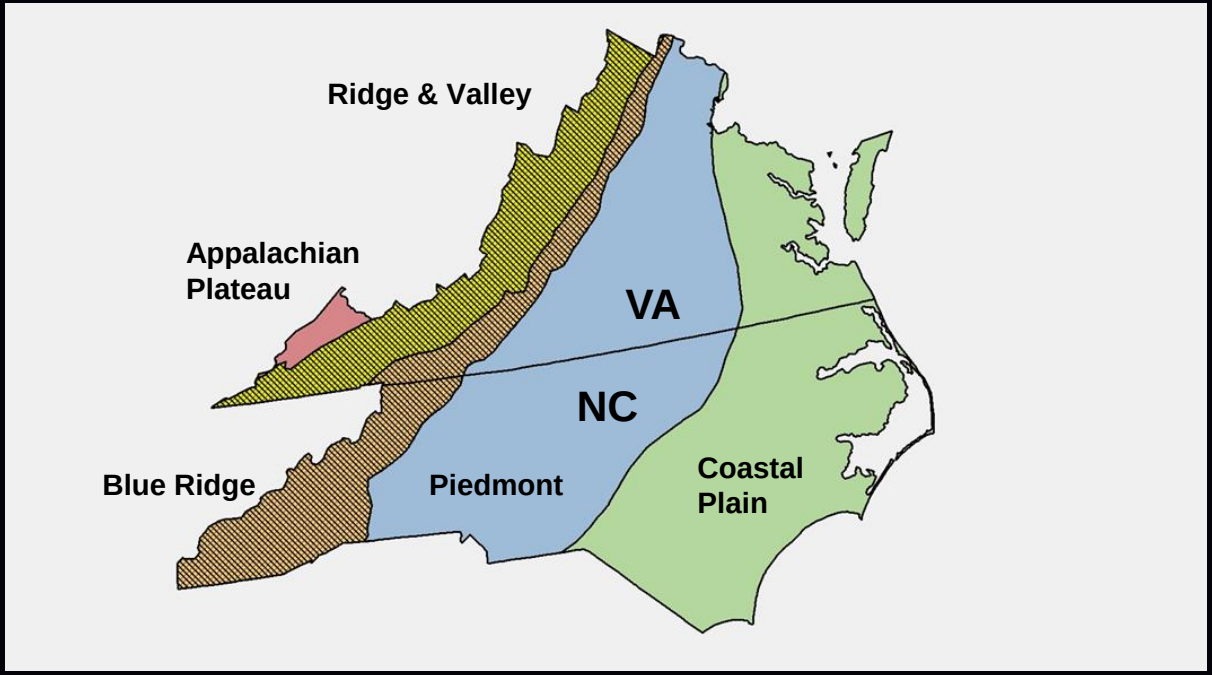
METHODS

Characterization Of Small Landscapes

1. NC Blue Ridge and VA Blue Ridge and Ridge & Valley were sectioned into 59,358 1 km^2 local landscapes

2. For all local landscapes:

30 yr mean Jan Temp (Max, Min, Mean)	PRISM
30 yr mean July Temp (Max, Min, Mean)	PRISM
30 yr mean Jan, July, Annual Precipitation	PRISM
Elevation (Mean, SD)	USGS Topo
Land cover: %Forest, %Ag, %Urban	NLCD
Fragmentation of Forest by Ag & Urban (Mean, SD)	Guido's Toolbox
Forest Contagion (Mean, SD)	Guido's Toolbox
Total Edge Diversity (Mean, SD)	Guido's Toobox



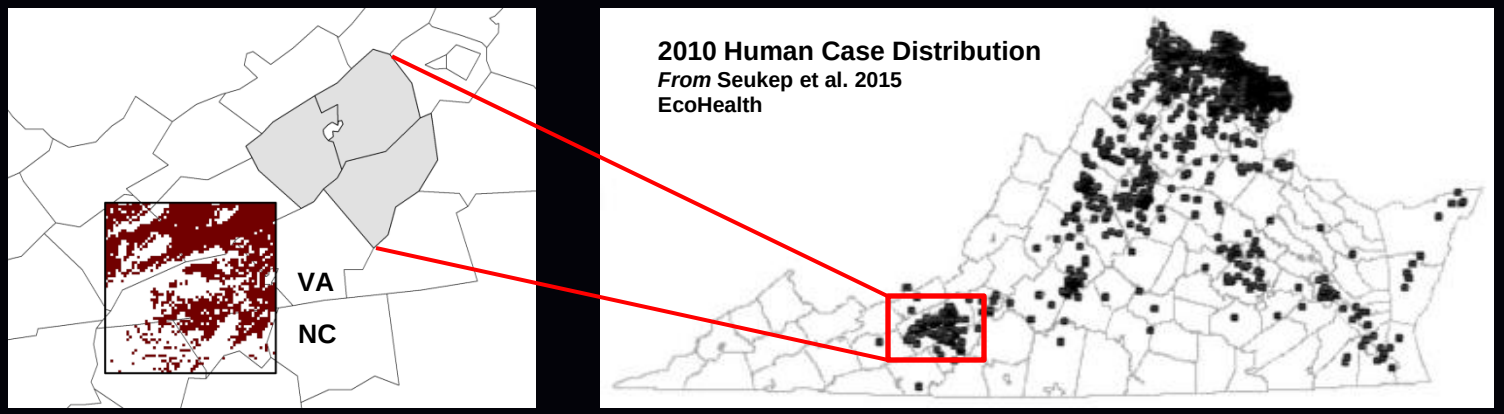
METHODS

LOCAL LANDSCAPE SIMILARITY ANALYSIS

1. Principal component analysis of the 1 km^2 landscapes found in Pulaski, Montgomery & Floyd counties to choose the most representative local landscape

2. Inverse of Euclidean distance (0,1) of other local landscapes from the representative landscape

3. Use three levels of similarity (.9, .85, .8) to map potential locations

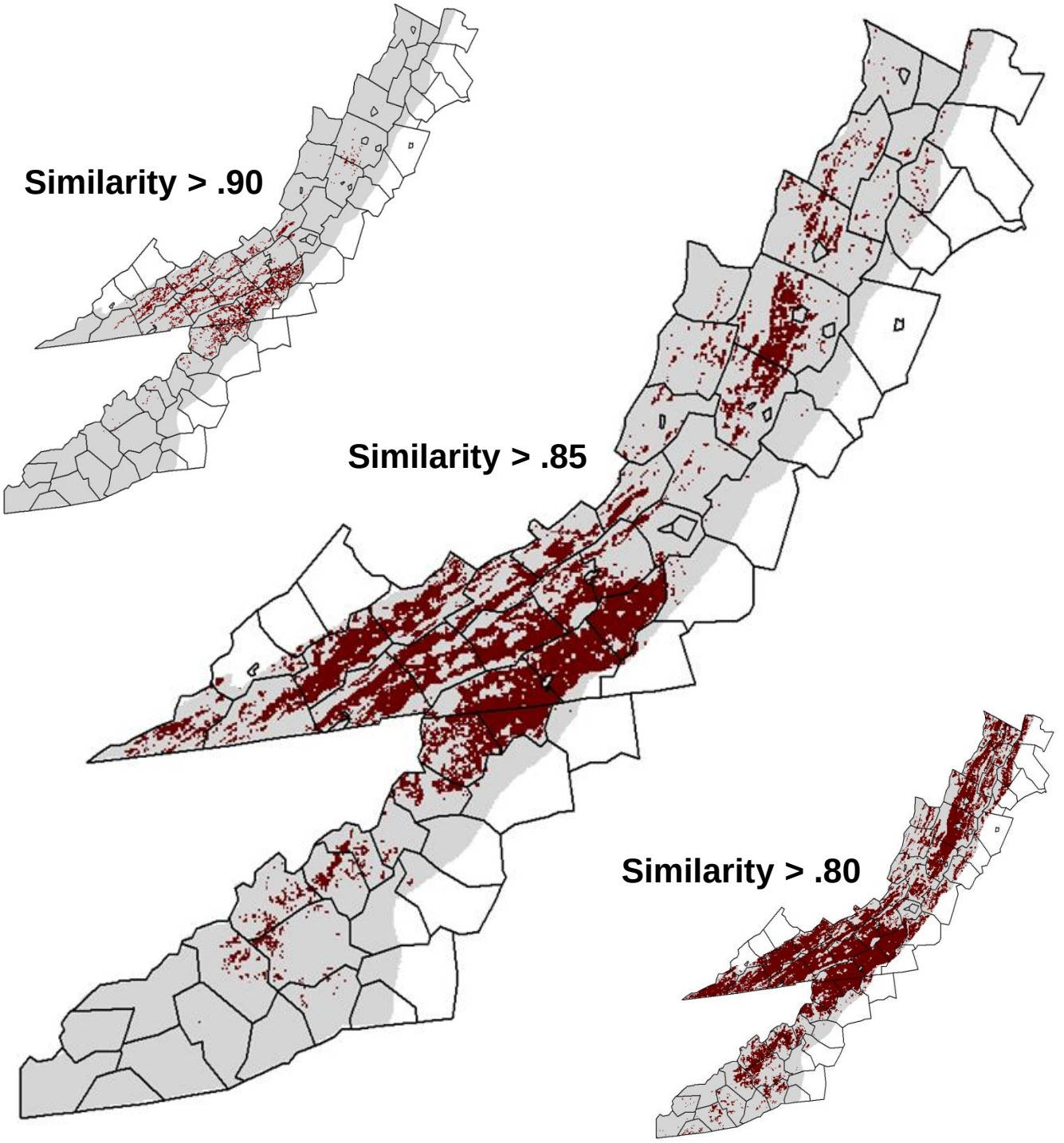


RESULTS

LOCAL LANDSCAPE SIMILARITY ANALYSIS

Similarity is a flexible measure – allowing users to consider how "stringently" similarity is defined

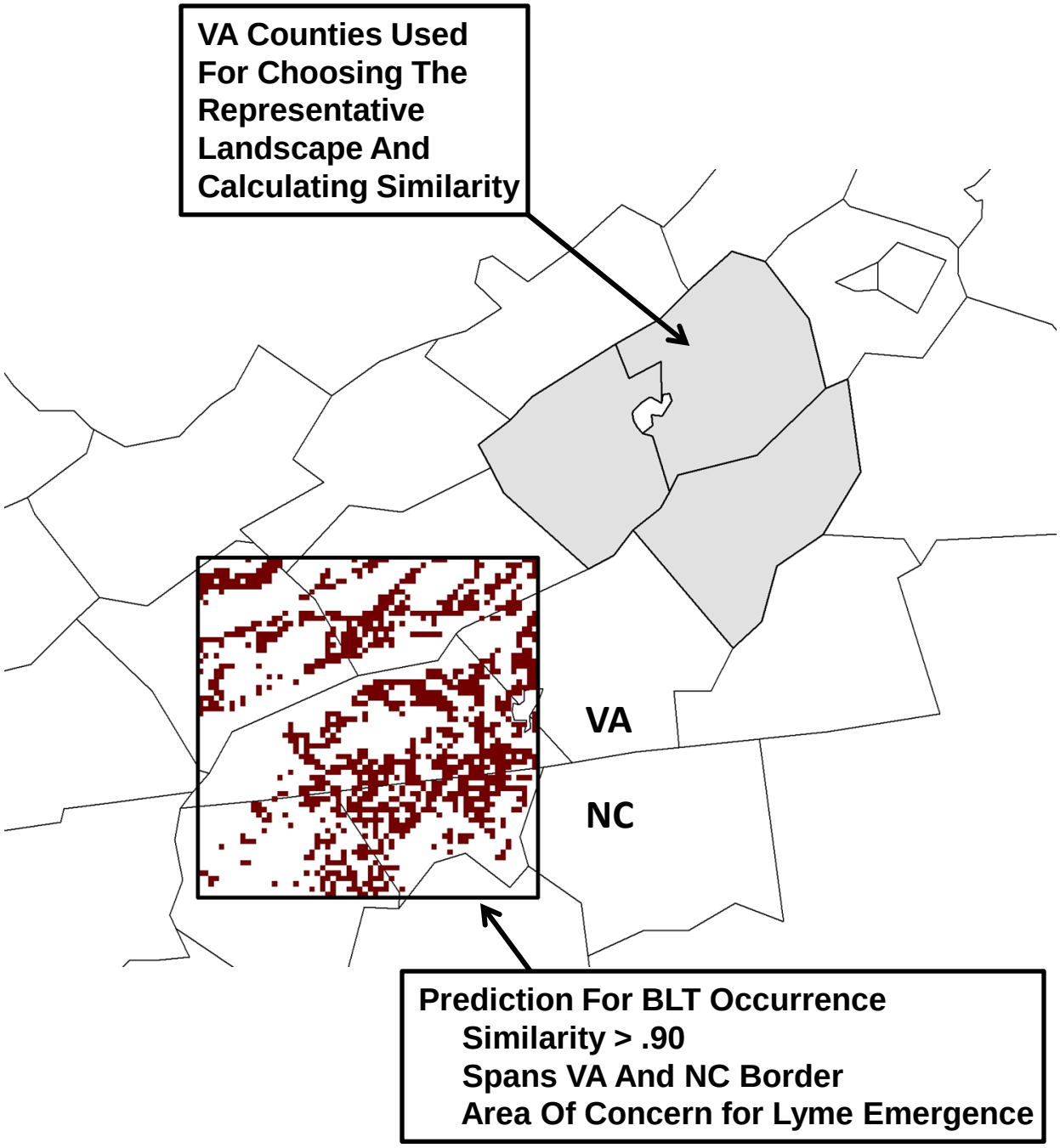
Just judging by high similarity in landscape composition, landscape configuration, and climate, much of the western NC Blue Ridge should be suitable for Blacklegged tick population establishment



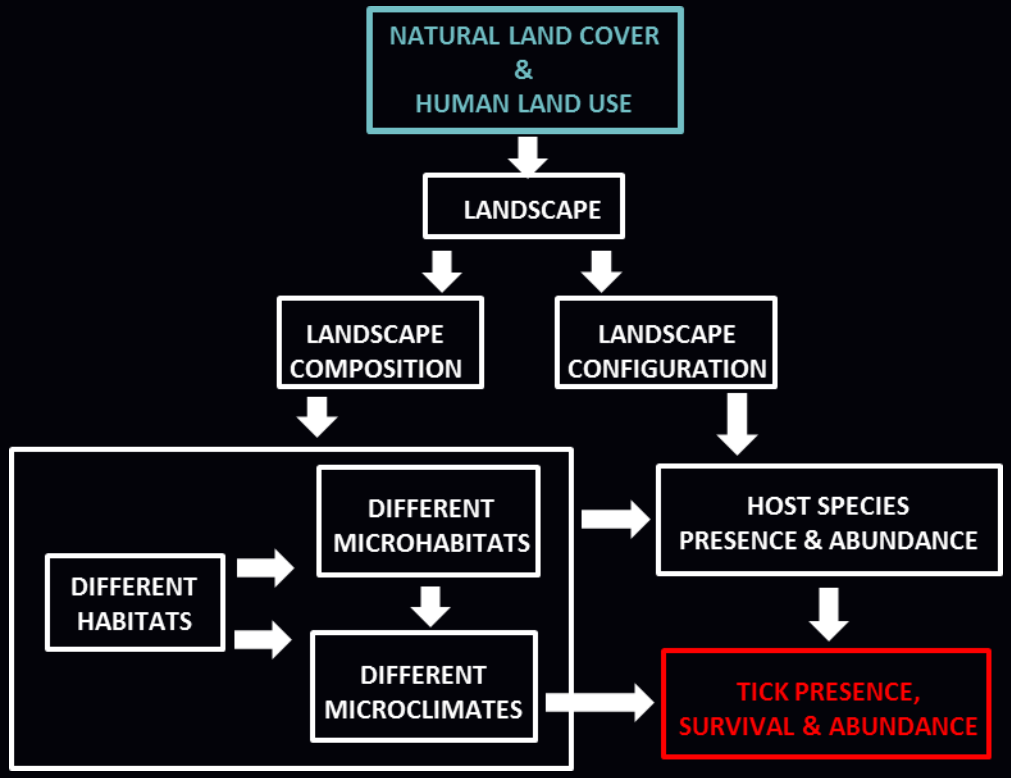
SUMMARY

Resulting maps can be viewed as a hypothesis for tick occurrence that can be tested by field sampling

Similarity can be used to design surveillance activities for Blacklegged tick occurrence



DISTRIBUTION, RELATIVE ABUNDANCE AND RICKETTSIA INFECTION RATE OF TICKS IN MECKLENBURG COUNTY, NC

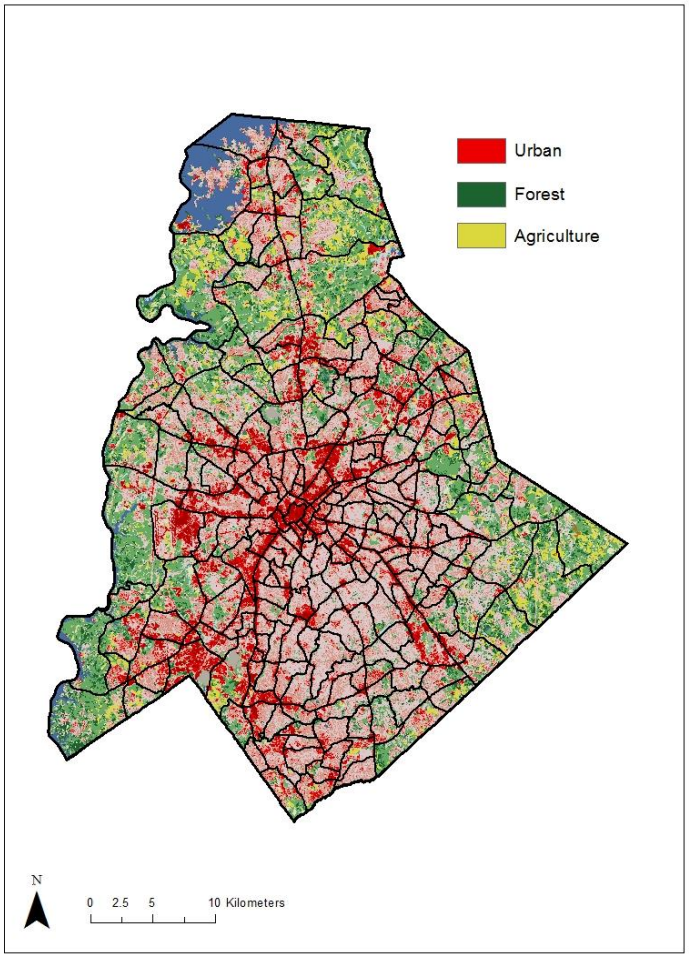


Hierarchy Level: Land Use/Cover Type or Habitat

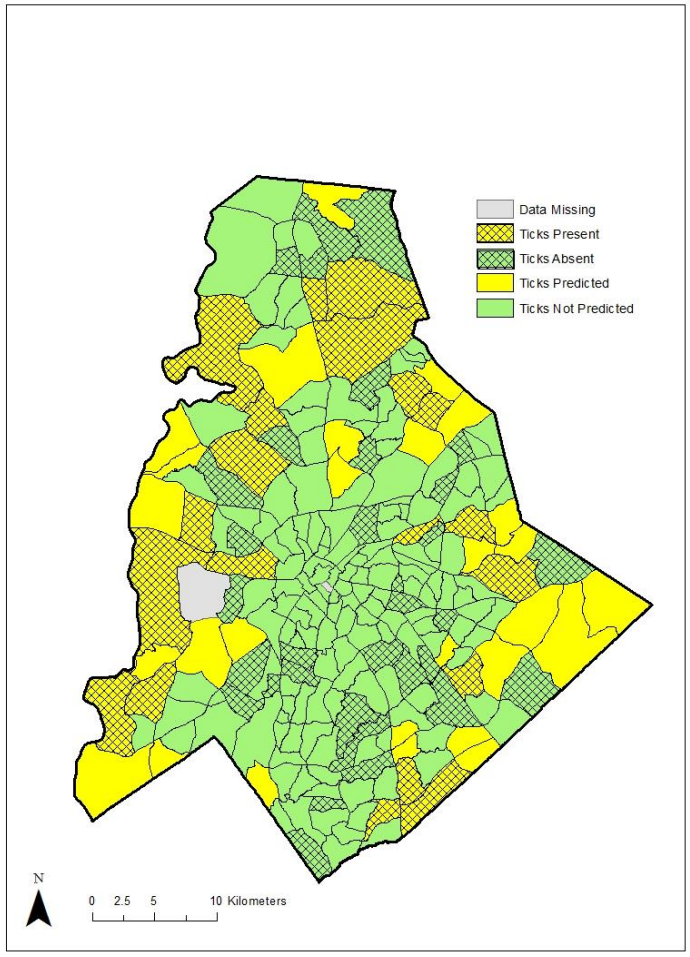
Resolution: Hectare/acre down to 20 m^2

Response Variable: Tick presence/abundance

MECKLENURG COUNTY LAND USE AND COVER



EMPIRICAL AND PREDICTED TICK OCCURRENCE BY CENSUS TRACT



INFECTION RATE: **LONE STAR – 64%**
GULF COAST – 75%

AMERICAN DOG TICK	LONE STAR TICK	GULF COAST TICK

SUMMARY

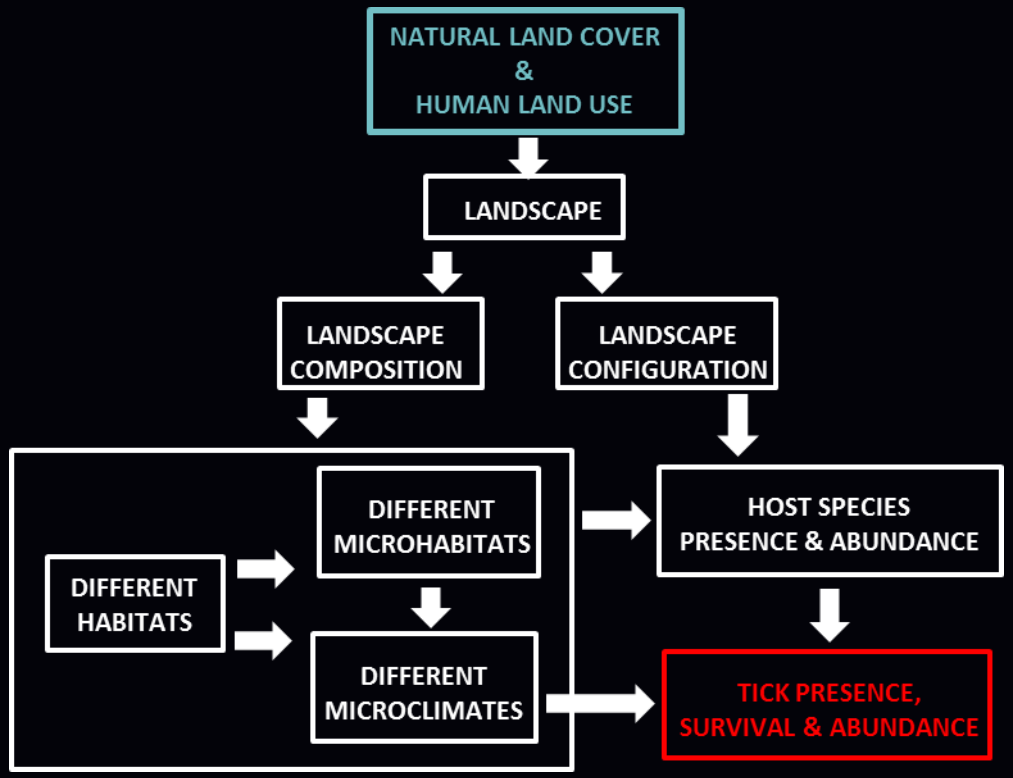
All tick species are patchy in occurrence

The most abundant tick species in Mecklenburg County is the Gulf Coast tick, which was found exclusively in edge and old field habitat

The Lone Star tick is locally common mostly in pine dominated forests*

When collected, both the Gulf Coast and Lone Star ticks display high rates of infection with *Rickettsia parkerii* and *R. amblyommi*, respectively

HABITAT, MICROHABITAT AND MICROCLIMATE EFFECTS ON THE DISTRIBUTION AND DENSITY OF THE LONE STAR TICK (*AMBLYOMMA AMERICANUM*) IN NORTH CAROLINA



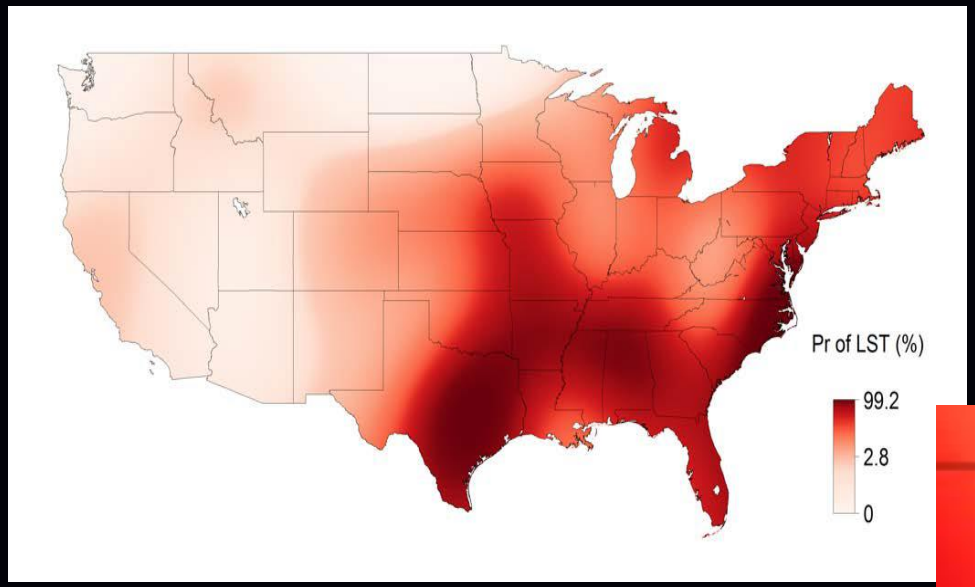
Hierarchy Level: Habitat and microhabitat
Resolution: 20 m^2 to .05 ha (.13 ac)
Response Variable: Tick presence/abundance

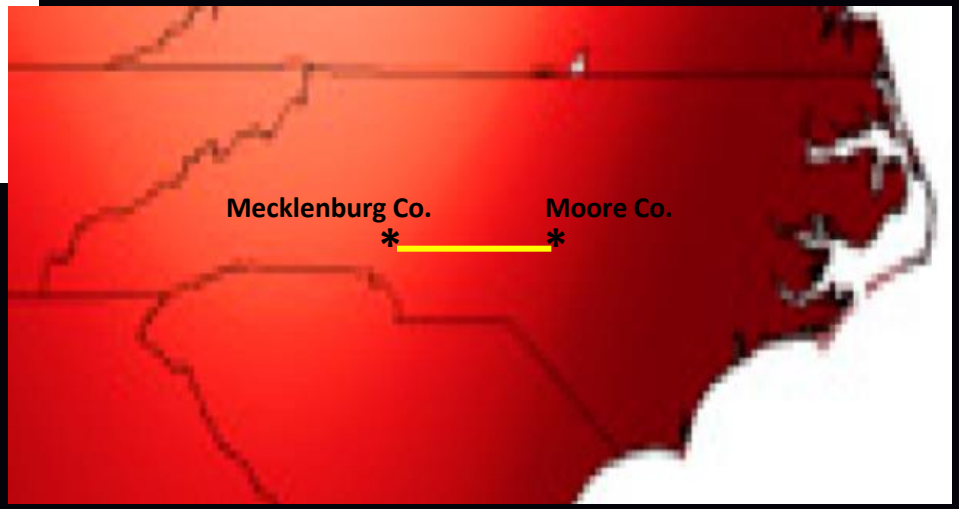
PREDICTED DISTRIBUTION AND DENSITY OF THE LONE STAR TICK (AMBLYOMMA AMERICANUM)

Am. J. Trop. Med. Hyg., 94(1), 2016, pp. 35–42
doi:10.4269/ajtmh.15-0580

Expanding Range of *Amblyomma americanum* and Simultaneous Changes in the Epidemiology of Spotted Fever Group Rickettsiosis in the United States

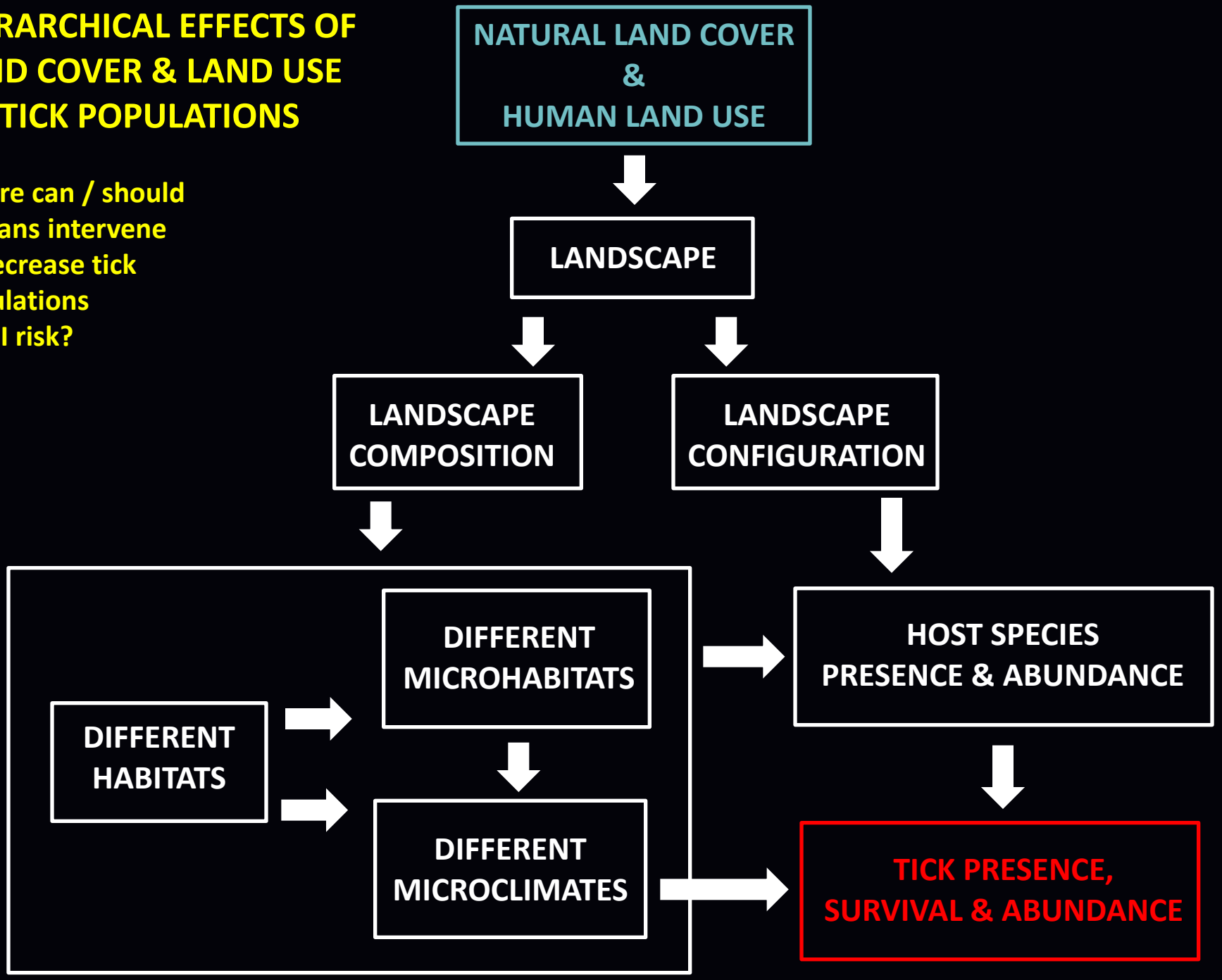
F. Scott Dahlgren,* Christopher D. Paddock, Yuri P. Springer, Rebecca J. Eisen, and Casey Barton Behravesh





HIERARCHICAL EFFECTS OF LAND COVER & LAND USE ON TICK POPULATIONS

Where can / should humans intervene to decrease tick populations & TBI risk?



From the literature …

LAND USE MANIPULATIONS AND MANAGEMENT AIMED AT TBI

1. Managing landscape composition & configuration

Jackson, et al. 2006. Towards landscape design guidelines for reducing Lyme disease risk. International Journal of Epidemiology 35:315-322.

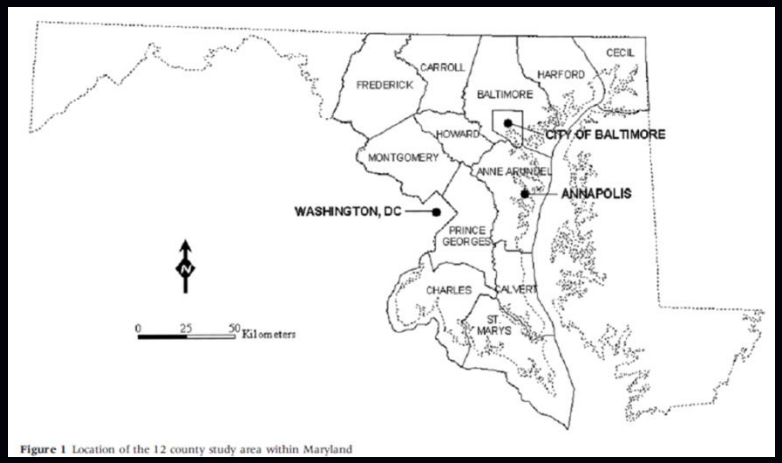


Figure 1 Location of the 12 county study area within Maryland

Lyme incidence was a function of:

Variable	Variance
Edge-Contrast Index	75%
Forest Percent	82%
Median Income	85%

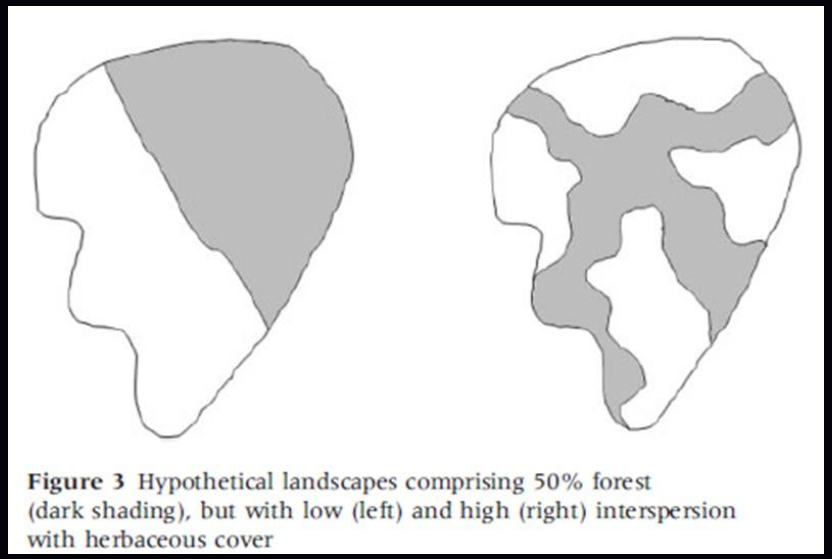


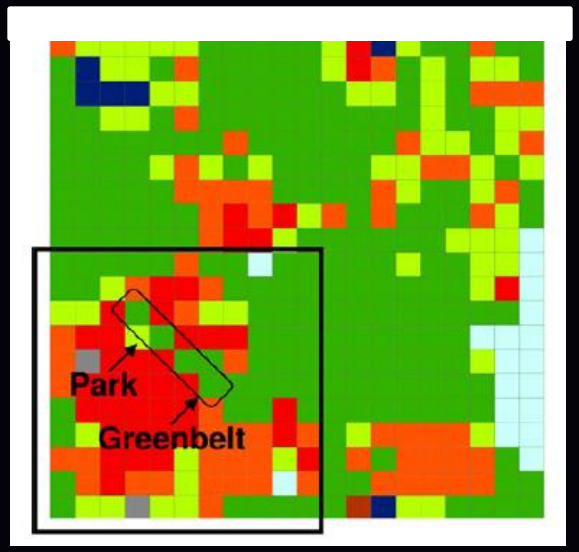
Figure 3 Hypothetical landscapes comprising 50% forest (dark shading), but with low (left) and high (right) interspersion with herbaceous cover

LAND USE MANIPULATIONS AND MANAGEMENT AIMED AT TBI

2. Landscape connectivity

Wang et al. 2012. Simulation of climate–host–parasite–landscape interactions: A spatially explicit model for ticks (Acari: Ixodidae). Ecological Modelling 243:42-62.

Purpose: To simulate the spatial-temporal dynamics of the lone star tick in response to changes in climatic conditions, landscape structure, and host community composition typical of the south-central United States



See also work by A. Estrada-Peña

Implications: Is the connectivity that promotes host species movement in urban and suburban areas a negative for landscape epidemiology?

What does this mean for the promotion of greenways that are planned and developed for promotion of other ecosystem services?

LAND USE MANIPULATIONS AND MANAGEMENT AIMED AT TBI

3. Habitat / microhabitat management

Prescribed burning
Forest stand thinning
Forest harvesting strategies
Invasive species removal

Fire: Used to promote pine timber production

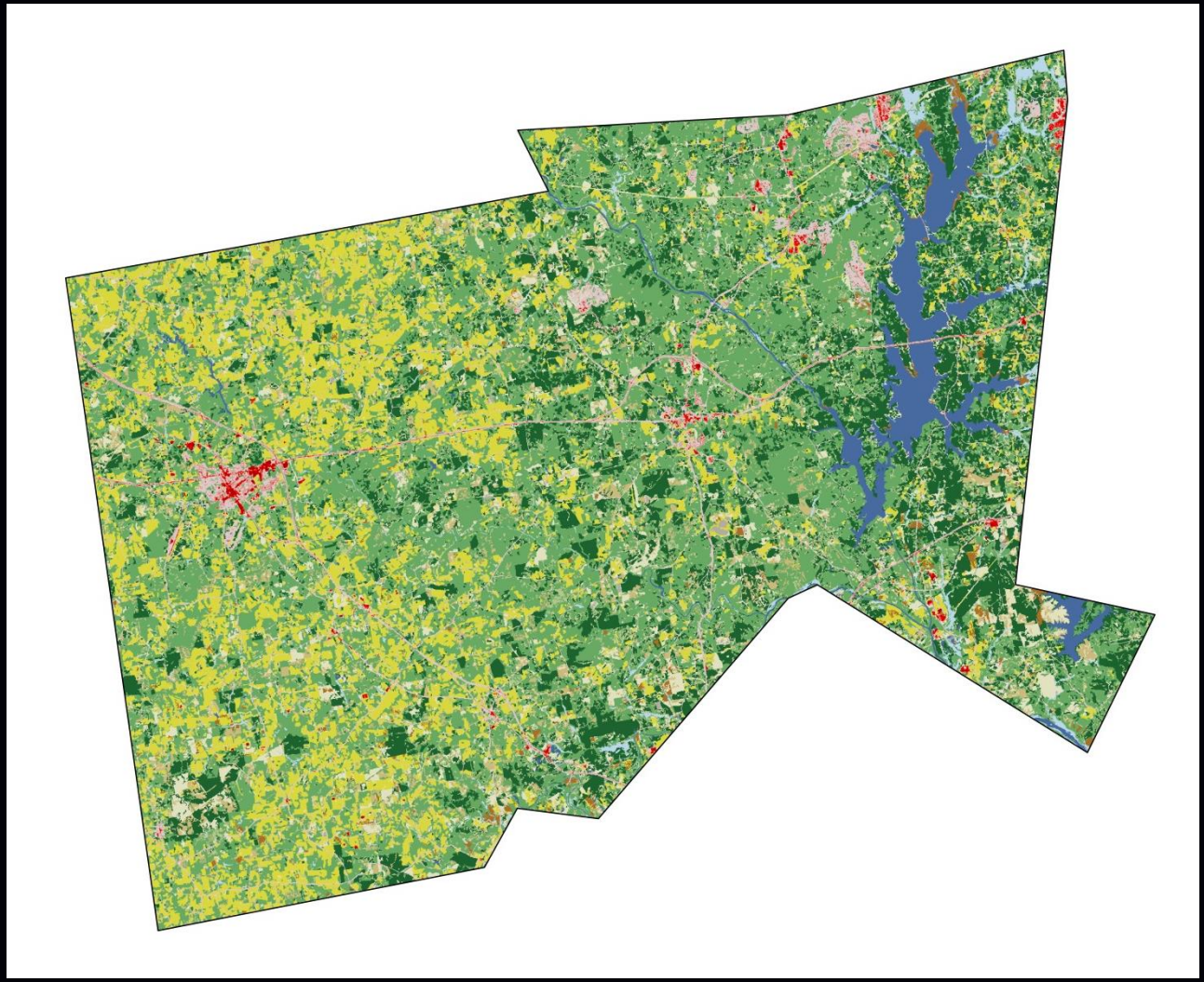
Should also decrease small mammal habitat suitability
Also decreases tick populations – at least temporarily

Allan, B.F. 2009. Journal of Medical Entomology 46:1030-1036. (*A. americanum*; Missouri)
Willis, D.W. et al. 2012. Journal of Vector Ecology 37:373-381. (*A. americanum*; Alabama)

THE LAND USE AND LAND COVER TEMPLATE OF CHATHAM COUNTY

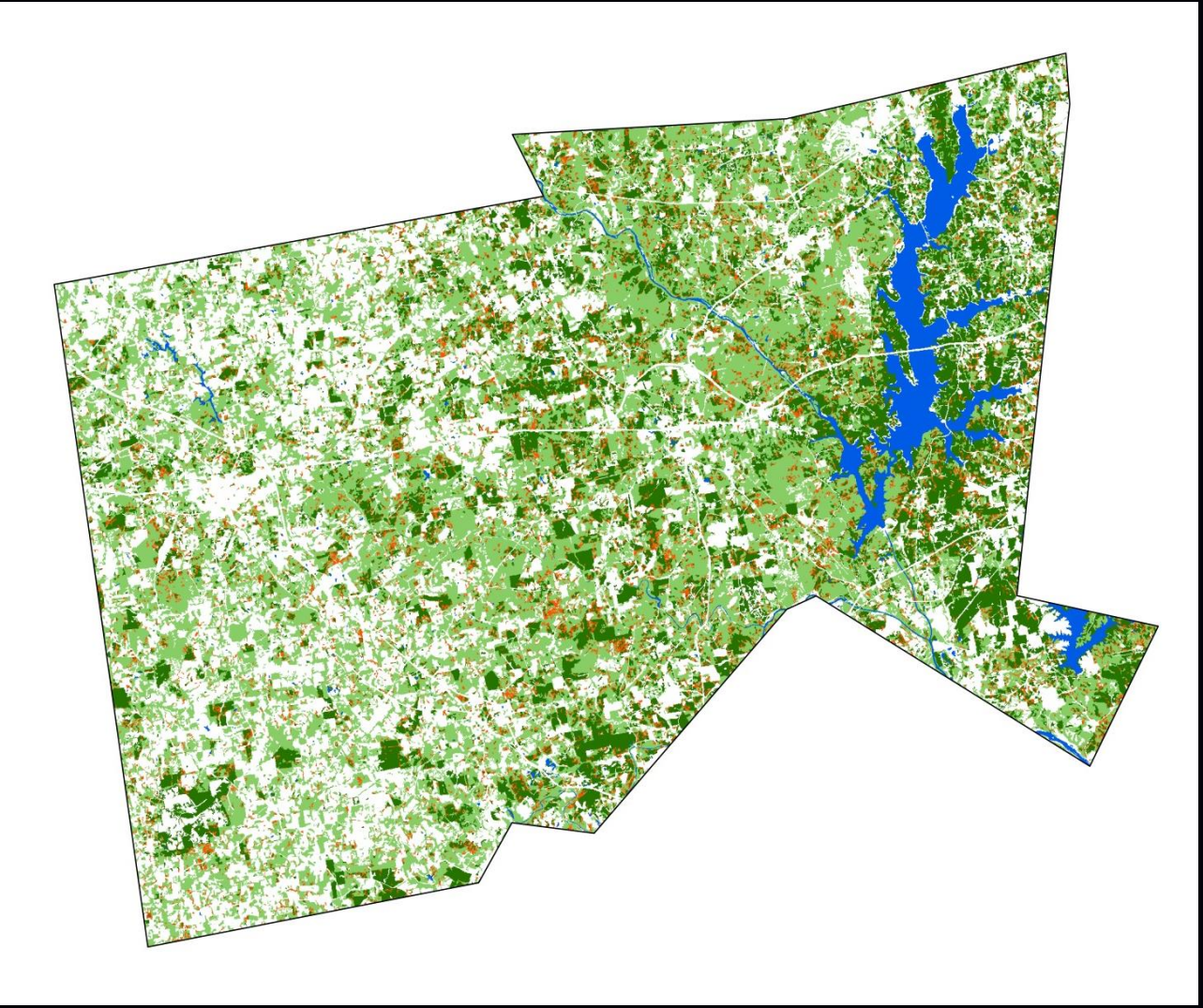
LAND USE AND LAND COVER

West: Smaller forest patches fragmented by more extensive agriculture
East: Lower forest fragmentation with more patches of pine forest



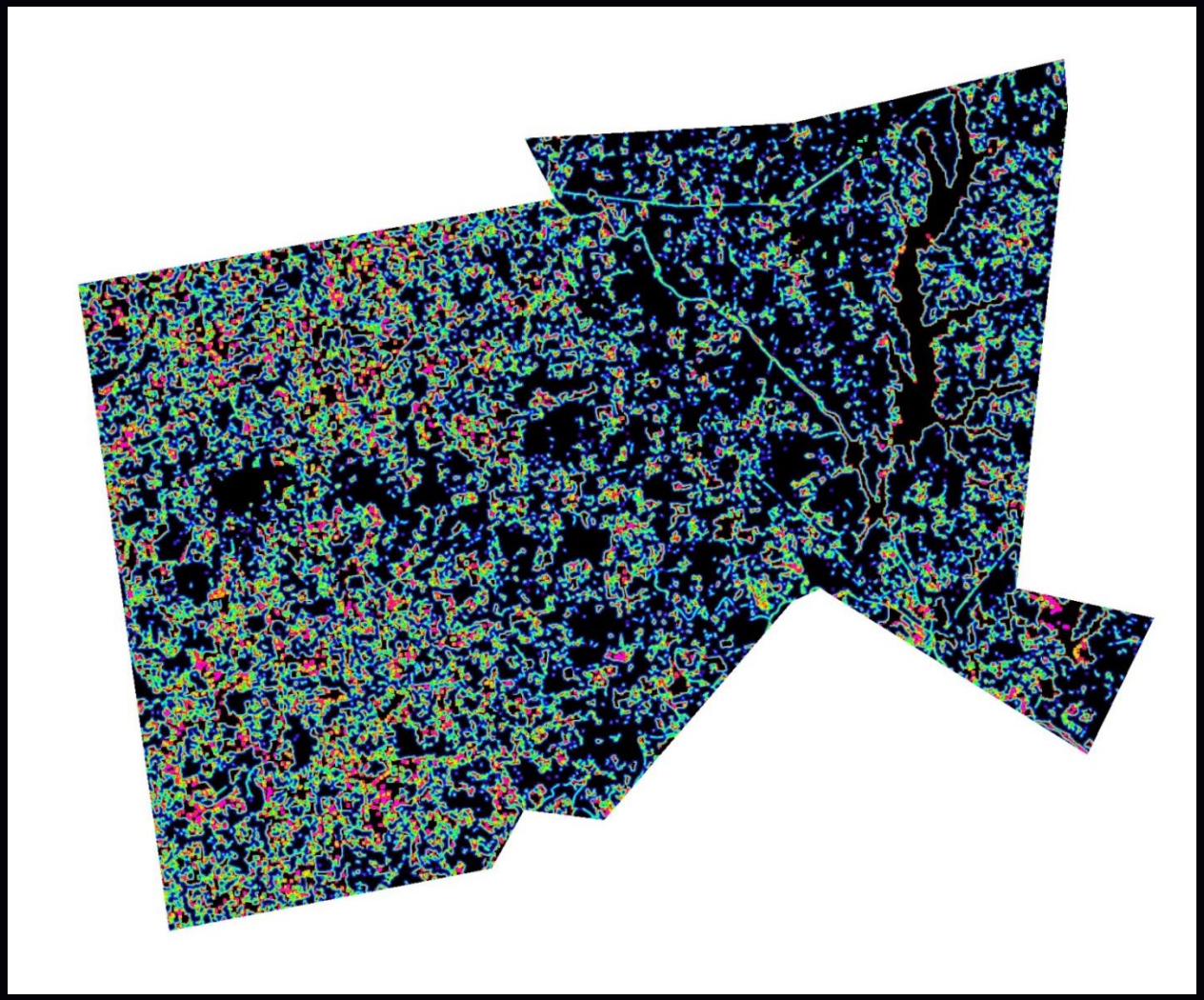
FOREST COVER

West: Smaller forest patches fragmented by more extensive agriculture
East: Lower forest fragmentation with more patches of pine forest



FOREST FRAGMENTATION BY AGRICULTURE

West: Greater amount of forest fragmented by agriculture with patches of very high edge
East: Lower amount and less intensity of forest fragmentation by agriculture



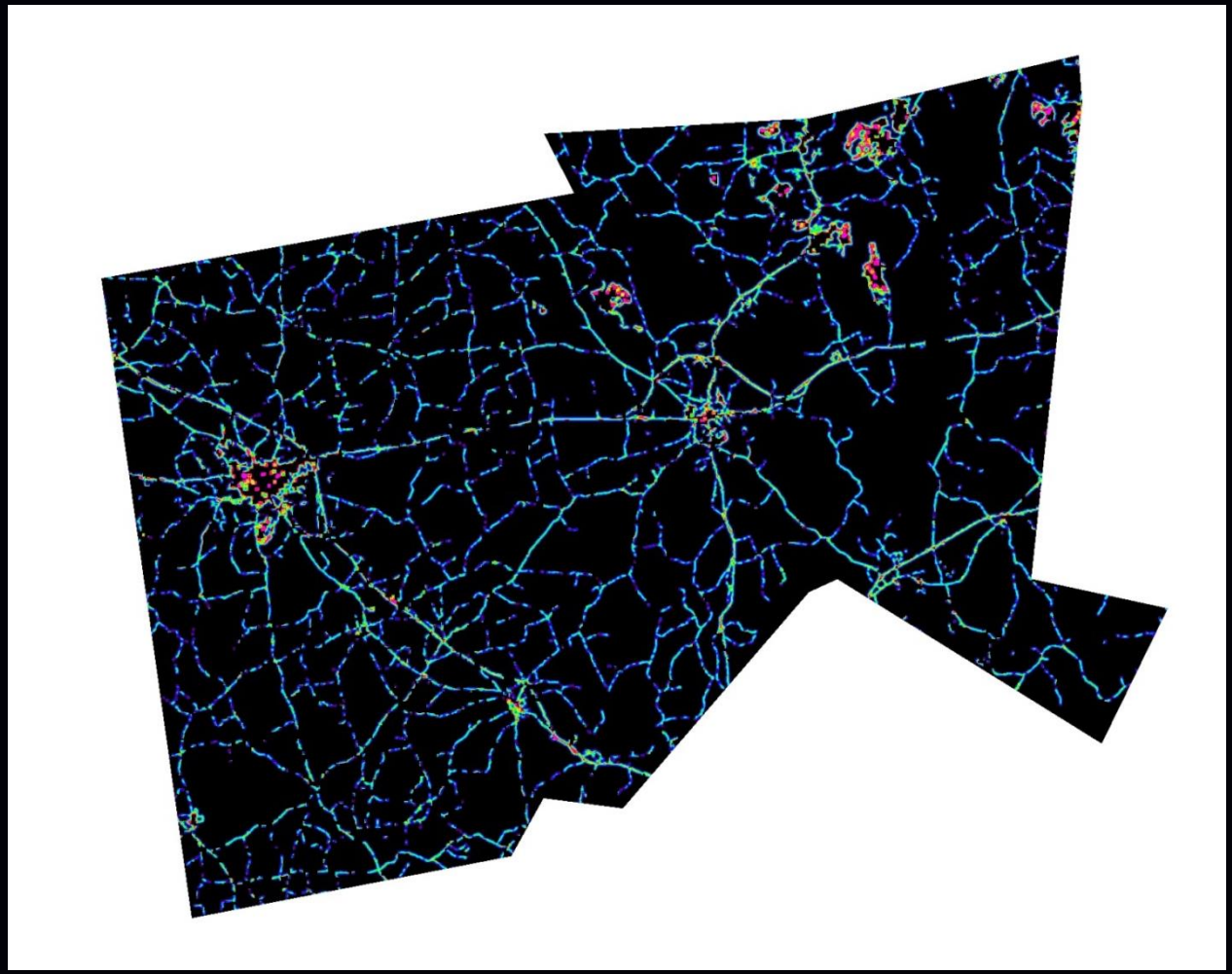
Brighter/hotter colors indicate the presence of more forest-agriculture edges

Black is unfragmented forest, water, and urban/suburban

Fragmentation was calculated from LULC data using a moving window of 5x5 pixels

FOREST FRAGMENTATION BY URBAN/SUBURBAN

Major roads and urban centers are apparent



Brighter/hotter colors indicate the presence of more forest-urban edges

Black is unfragmented forest, water, and agriculture

Fragmentation was calculated from LULC data using a moving window of 5x5 pixels

WHAT WOULD A SCIENCE GEEK WANT TO KNOW ABOUT CHATHAM COUNTY?

1. What is the distribution (with great precision) of human TBI cases, i.e. are cases clustered?
2. What is the distribution of tick species, densities, and infection rates?
3. What is the density and distribution of deer and other hosts?
4. How do answers to 1-3 correlate with land use patterns and fragmentation patterns?
5. Is there a critical density of deer that would need to be achieved before having a significant impact on tick populations?
6. Is there significant climate/microclimate variation within the county?

WHAT FUNDAMENTALS SHOULD UNERLIE A TBI MANAGEMENT PLAN?

1. There is probably not a silver bullet.
2. Promote tick management activities that simultaneously promote production of other ecosystem services.
3. Gain citizen support through citizen science.
4. Integrate human, economic, ecological, and environmental dimensions in management.
5. Approach TBI management in an adaptive management format.