Integrated Modeling of Land Use and Land Cover Change

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Overarching Question

How do land management decisions affect terrestrial ecosystems?

Land-use and land-cover change model

Artificial representations of interactions in the land-use system

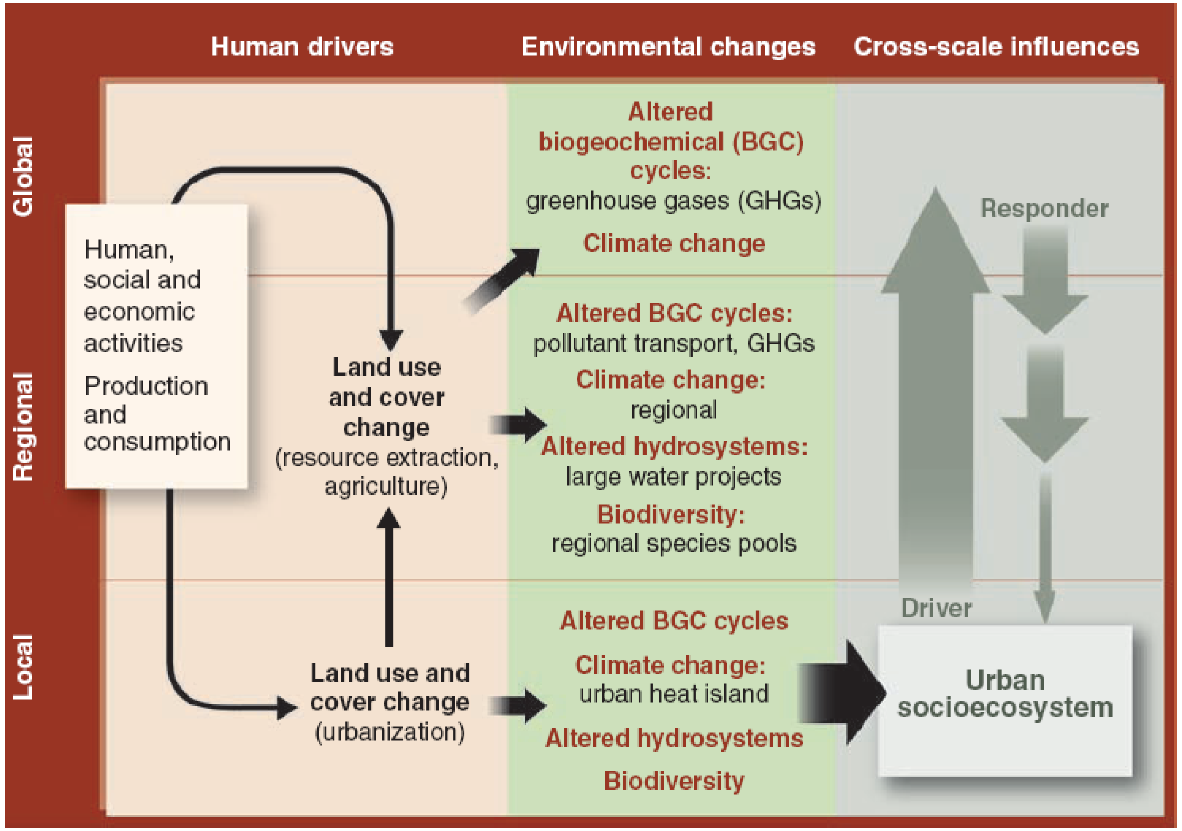
- Analyze the spatio-temporal dynamics
- Evaluate future development
- Test hypotheses

Methods

- Modelling and simulation
- Scenario exercise / alternative futures analyses

→Sustainable natural resource management

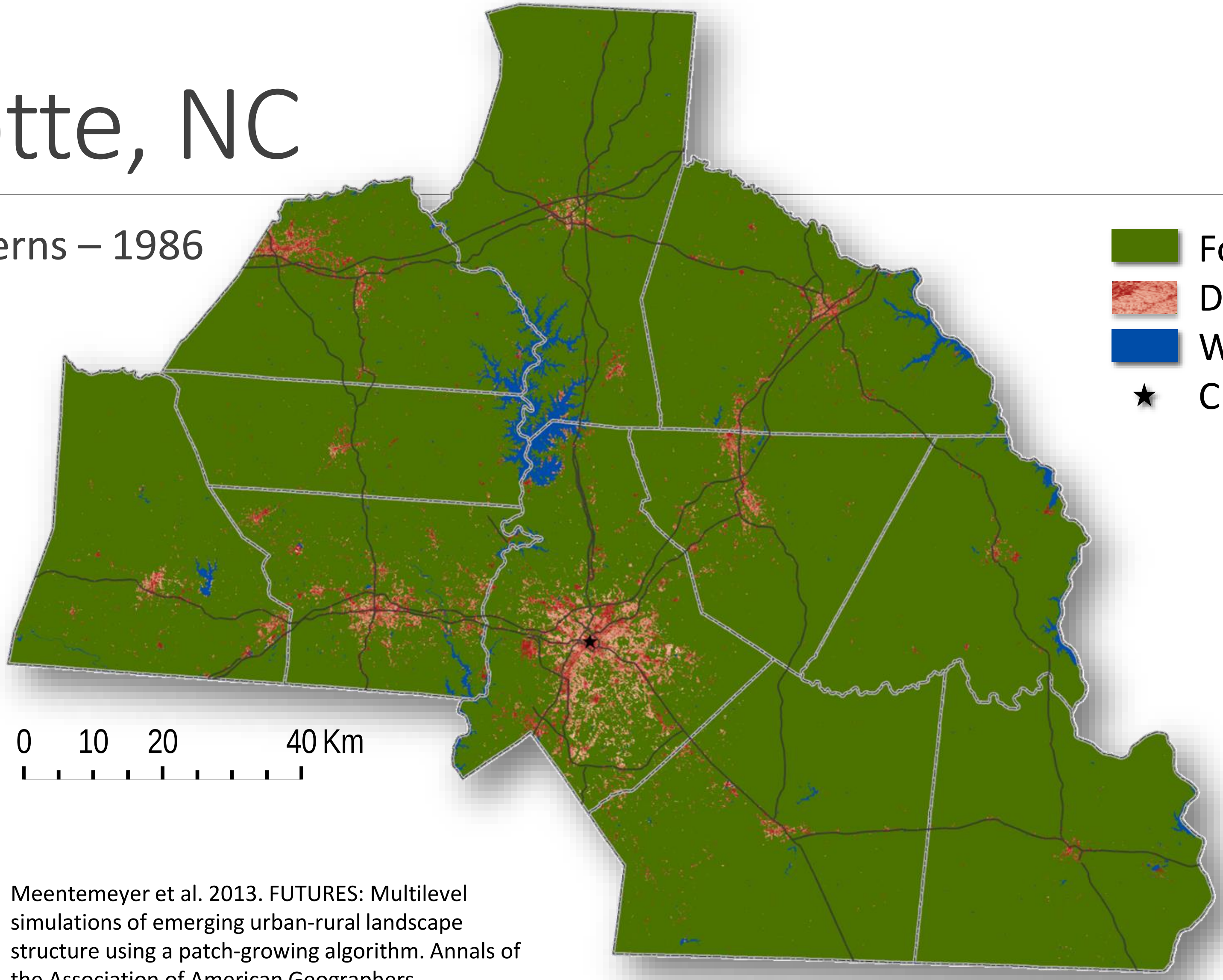
Urbanization

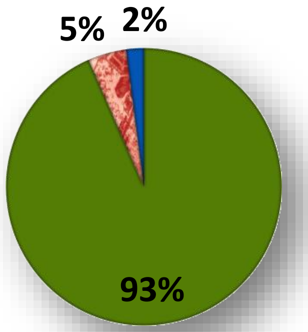


Grimm, N. et al. 2008. Global change and the ecology of cities. Science 319(5864): 756.

Charlotte, NC

Observed Patterns – 1986

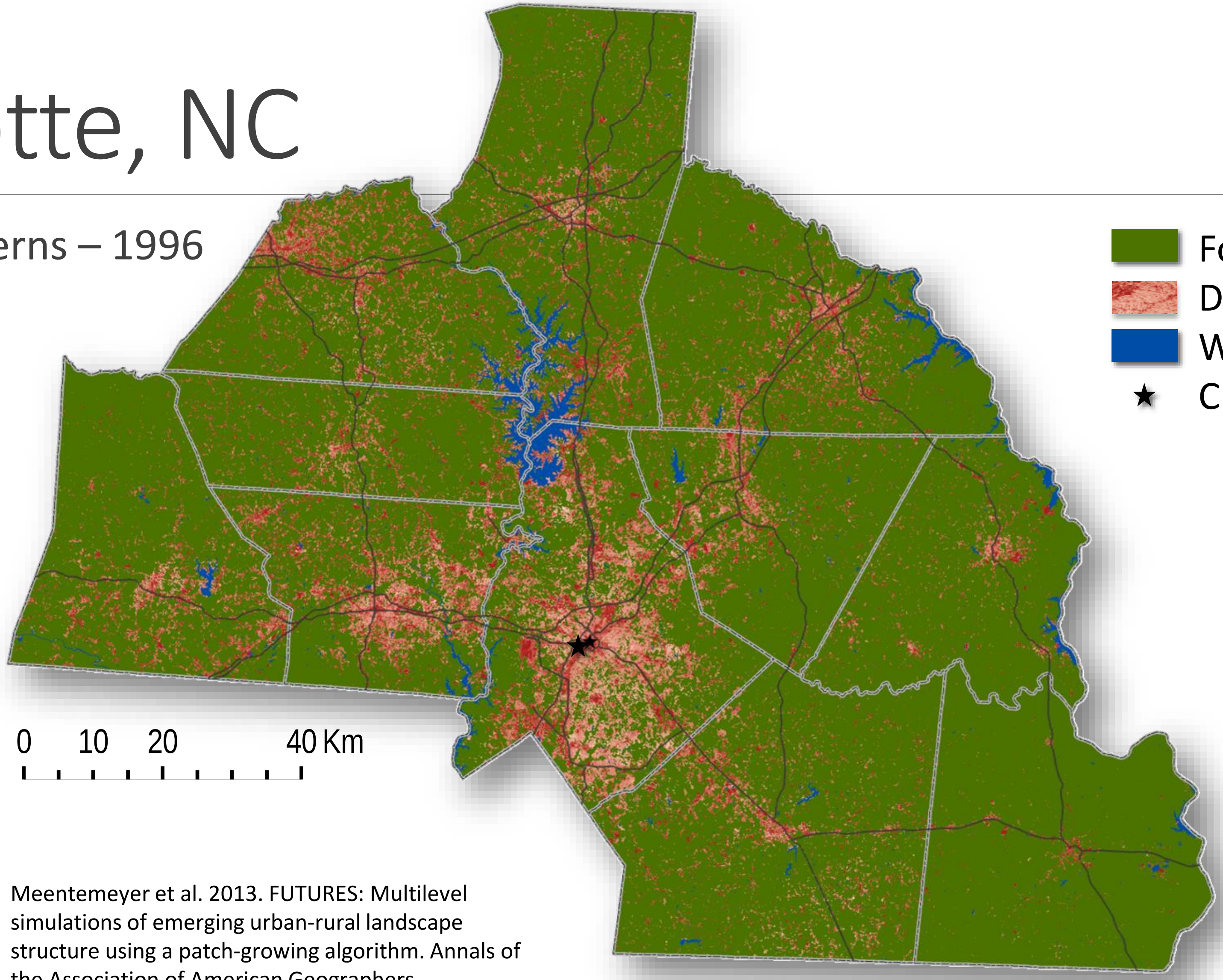


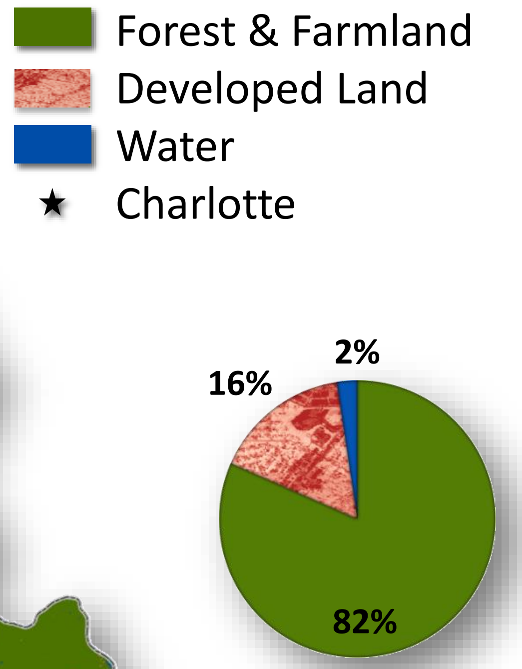


Meentemeyer et al. 2013. FUTURES: Multilevel simulations of emerging urban-rural landscape structure using a patch-growing algorithm. Annals of the Association of American Geographers

Charlotte, NC

Observed Patterns – 1996

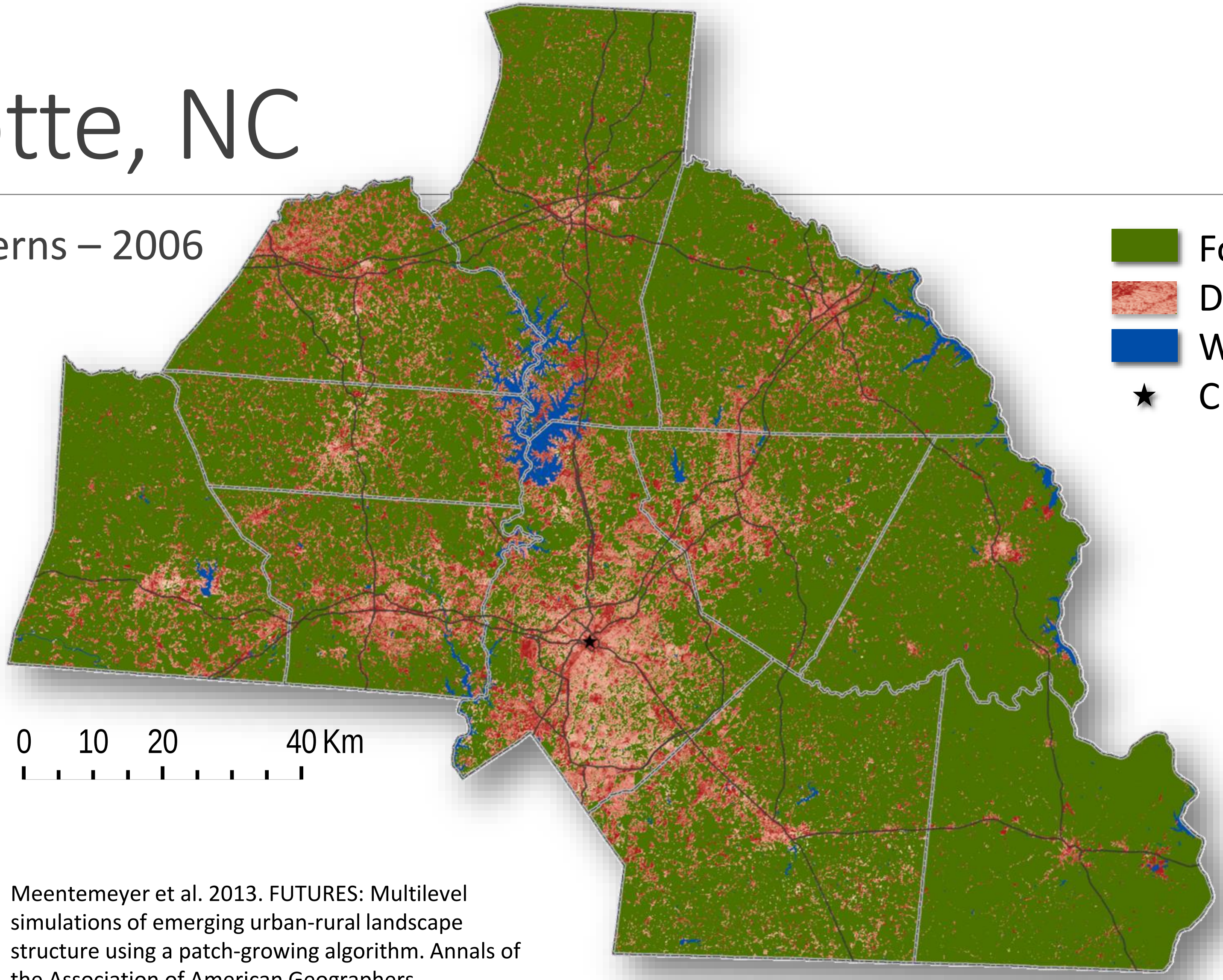


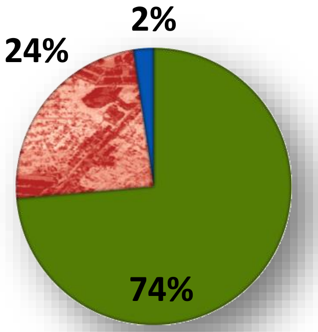


Meentemeyer et al. 2013. FUTURES: Multilevel simulations of emerging urban-rural landscape structure using a patch-growing algorithm. Annals of the Association of American Geographers

Charlotte, NC

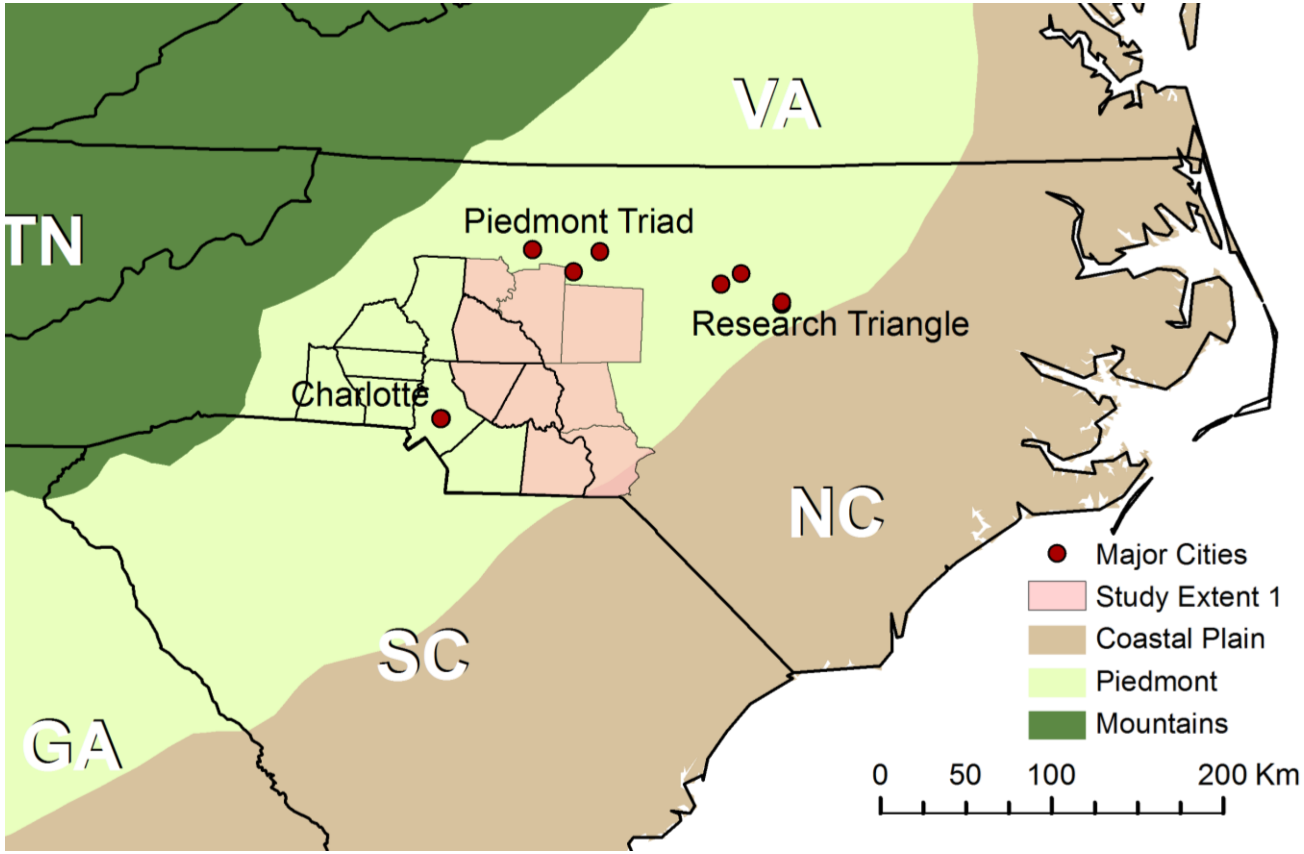
Observed Patterns – 2006





Meentemeyer et al. 2013. FUTURES: Multilevel simulations of emerging urban-rural landscape structure using a patch-growing algorithm. Annals of the Association of American Geographers

Charlanta Mega-region



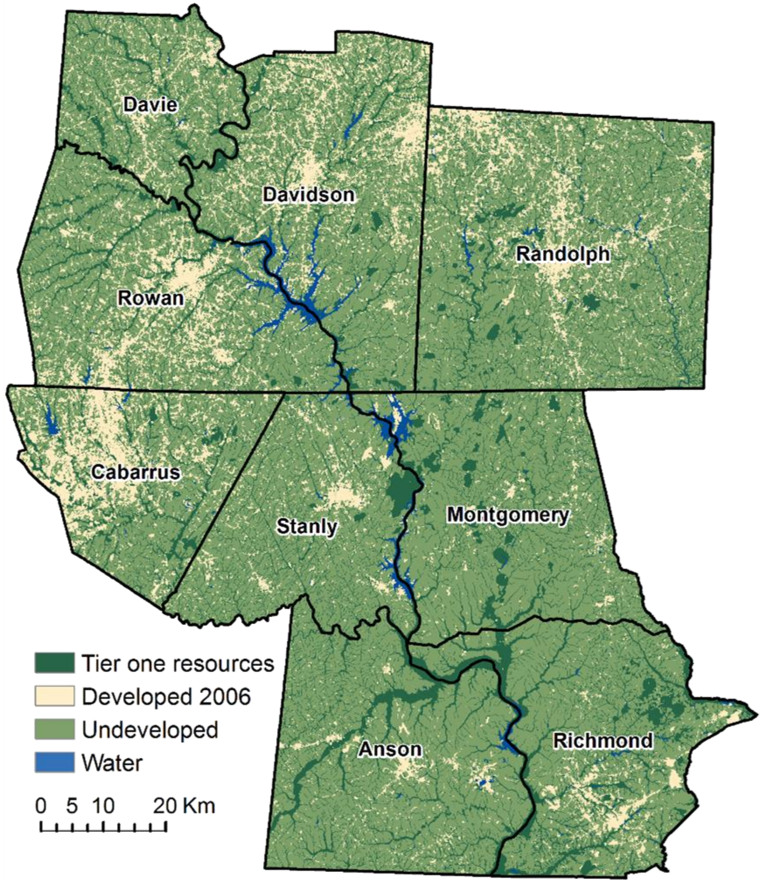
Objectives

1. Simulate urbanization patterns under different conservation based planning scenarios

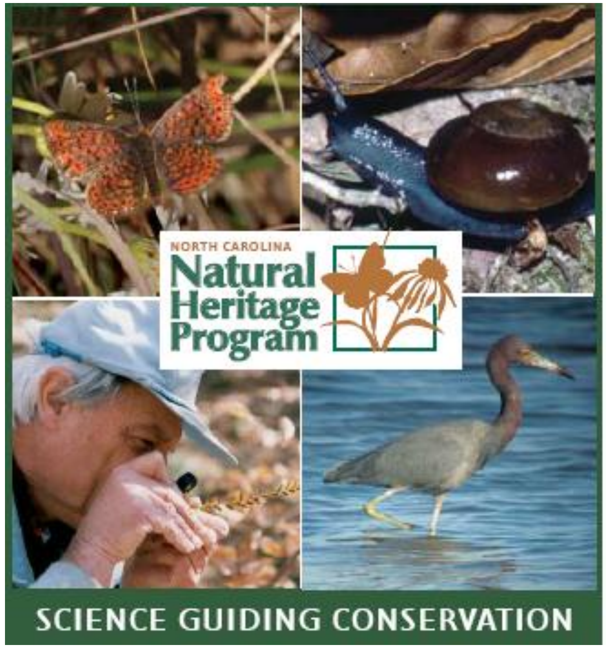
2. Assess resulting impacts to different conservation planning goals

Dorning, M.A.; Koch, J.; Shoemaker, D.A.; Meentemeyer R.K. (in review) *Simulating urbanization scenarios reveals tradeoffs between conservation planning strategies*. Landscape and Urban Planning.

Conservation Planning Goals

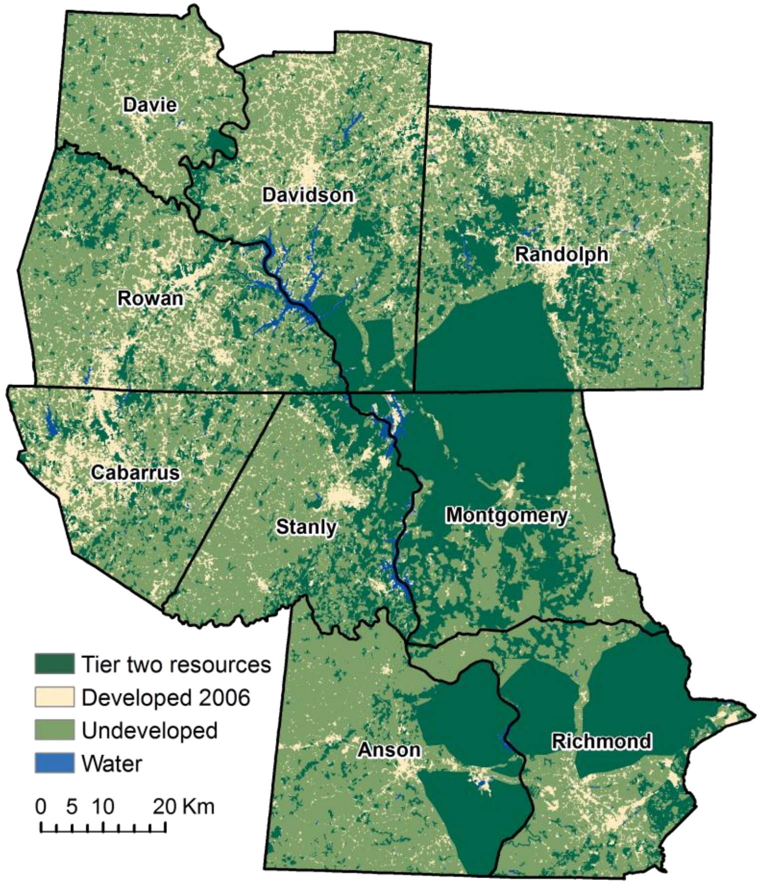


1. Protect Priority Resources



NCWRC. 2013. Green growth toolbox handbook.
http://www.ncwildlife.org/Conserving/Programs/GreenGrowthToolbox.aspx

Conservation Planning Goals



1. Protect Priority Resources

NCWRC. 2013. Green growth toolbox handbook.
http://www.ncwildlife.org/Conserving/Programs/GreenGrowthToolbox.aspx

Conservation Planning Goals

2. Limit Landscape Fragmentation

Conventional Subdivision

Farmland, grassland habitat and historical site are lost.

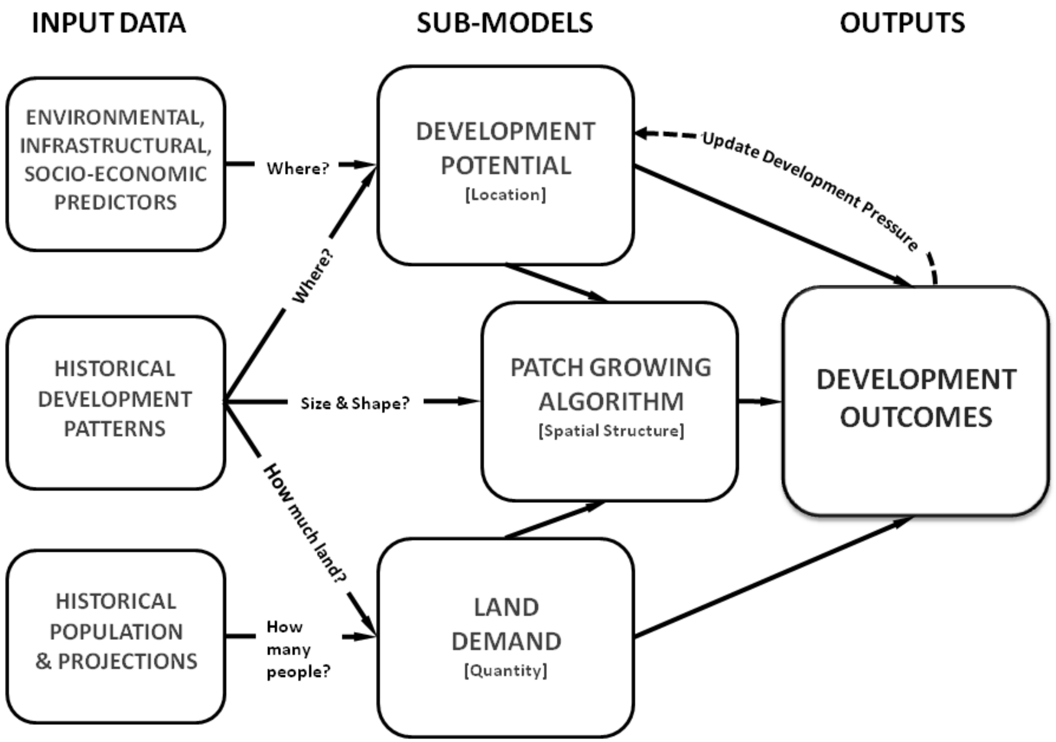
Image and information courtesy of Randall Arendt, from Arendt, R., M. Collins and A. Valentine (1996). Open Space Design Guidebook: Albemarle Pamlico Estuarine Region. Prepared for the North Carolina Association of County Commissioners. Media, PA, Natural Lands Trust.

Conservation Subdivision

Natural and historic features are properly identified prior to design and maintained. Grassland and forest wildlife habitat is managed with funds from the homeowner association. A biologist is contracted for habitat management.

NCWRC. 2013. Green growth toolbox handbook.
http://www.ncwildlife.org/Conserving/Programs/GreenGrowthToolbox.aspx

FUTURES



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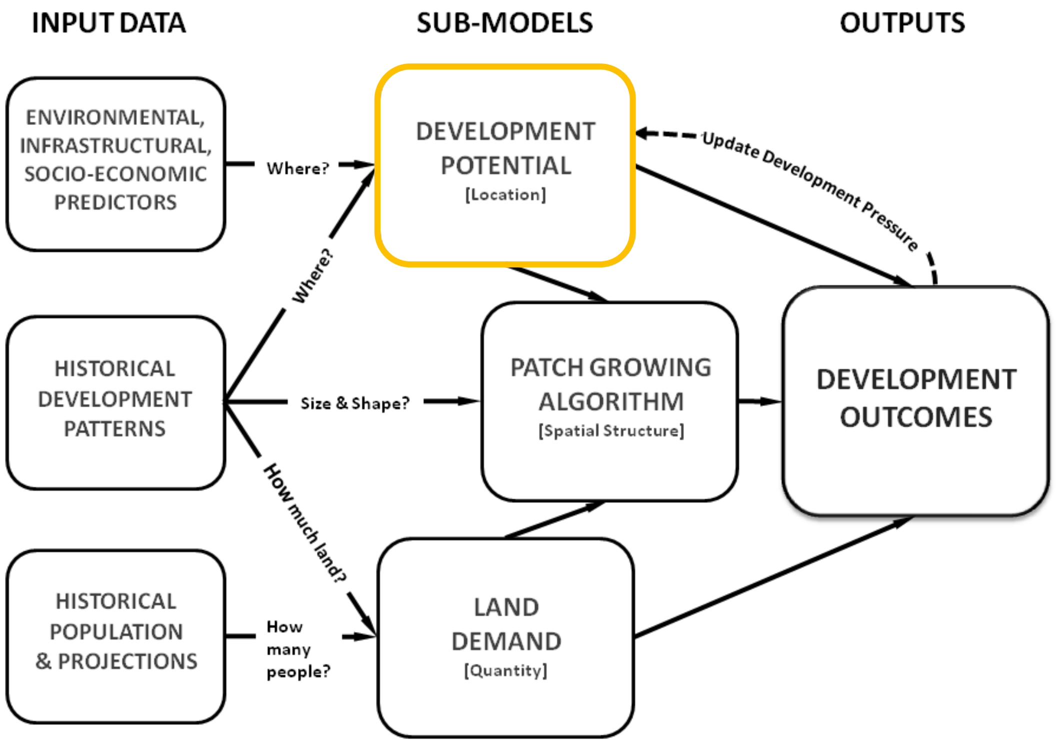
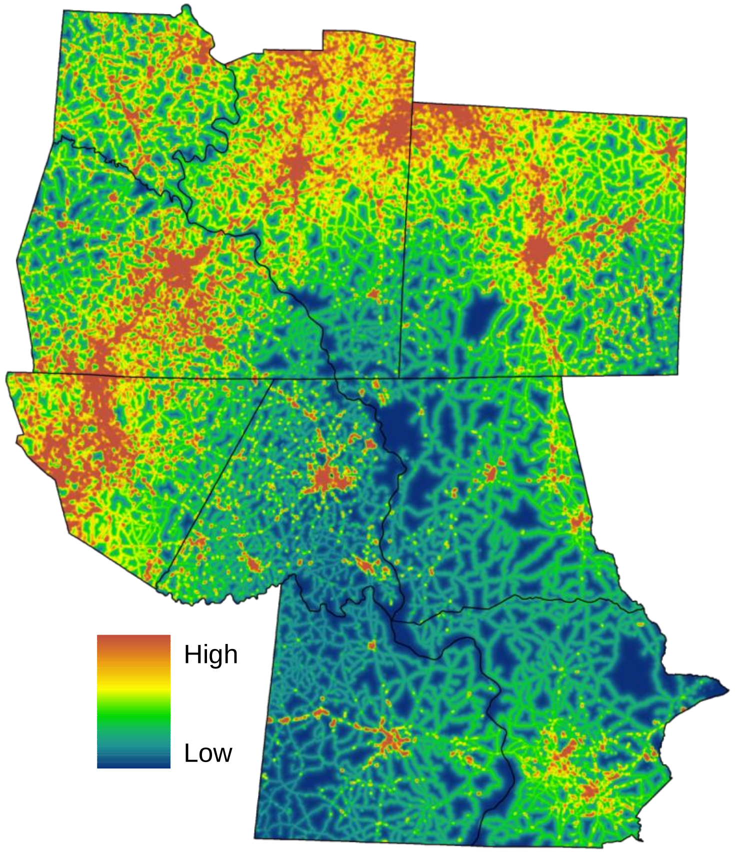
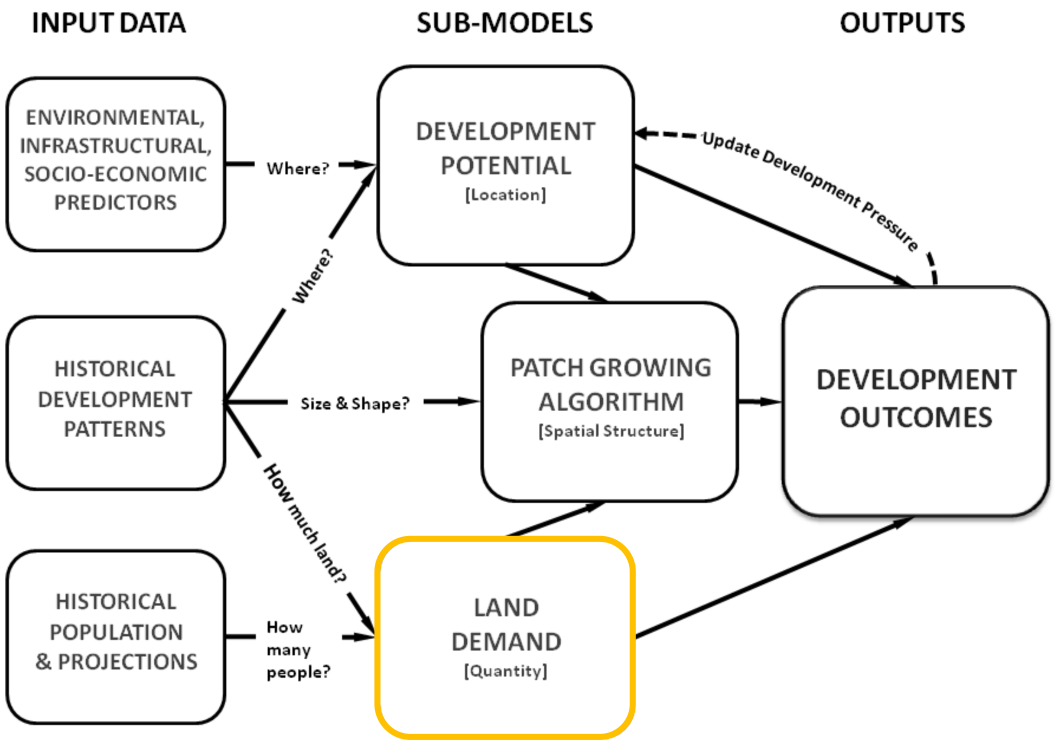
FUTURES



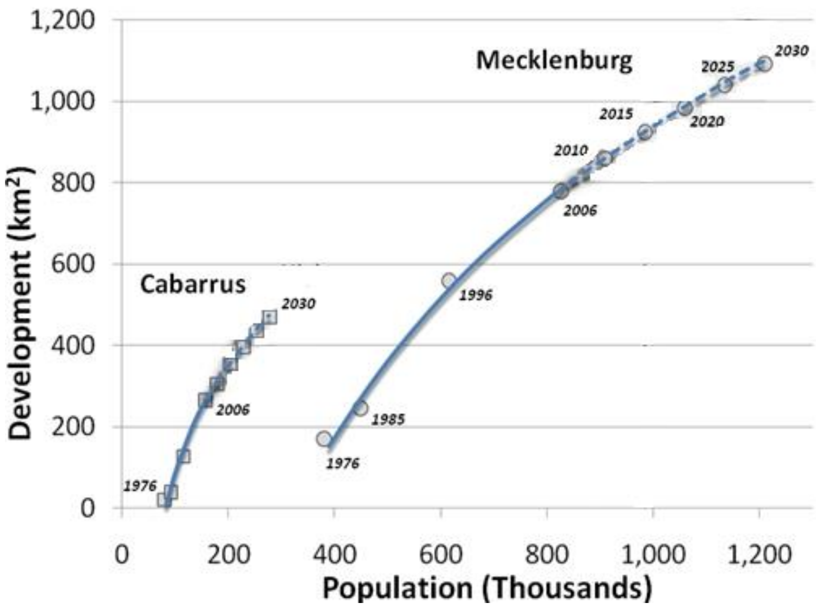
POTENTIAL



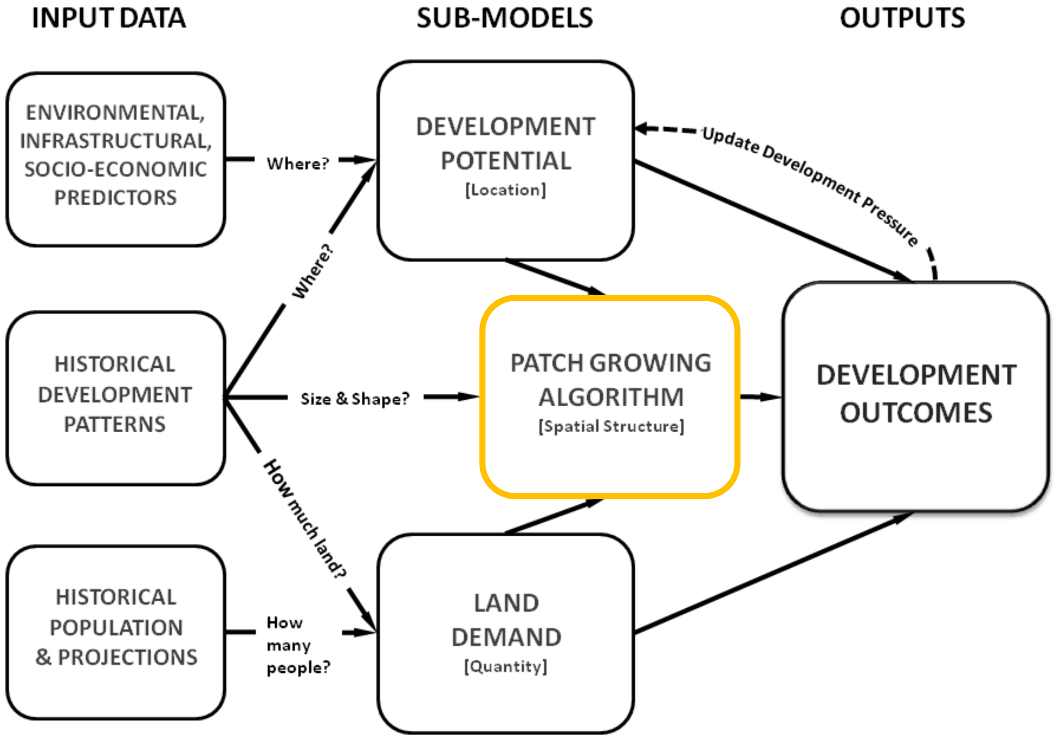
FUTURES



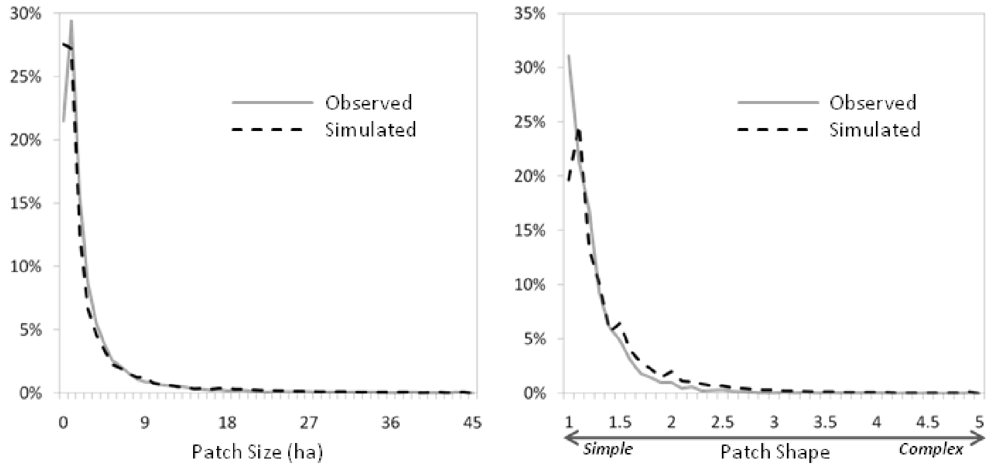
DEMAND



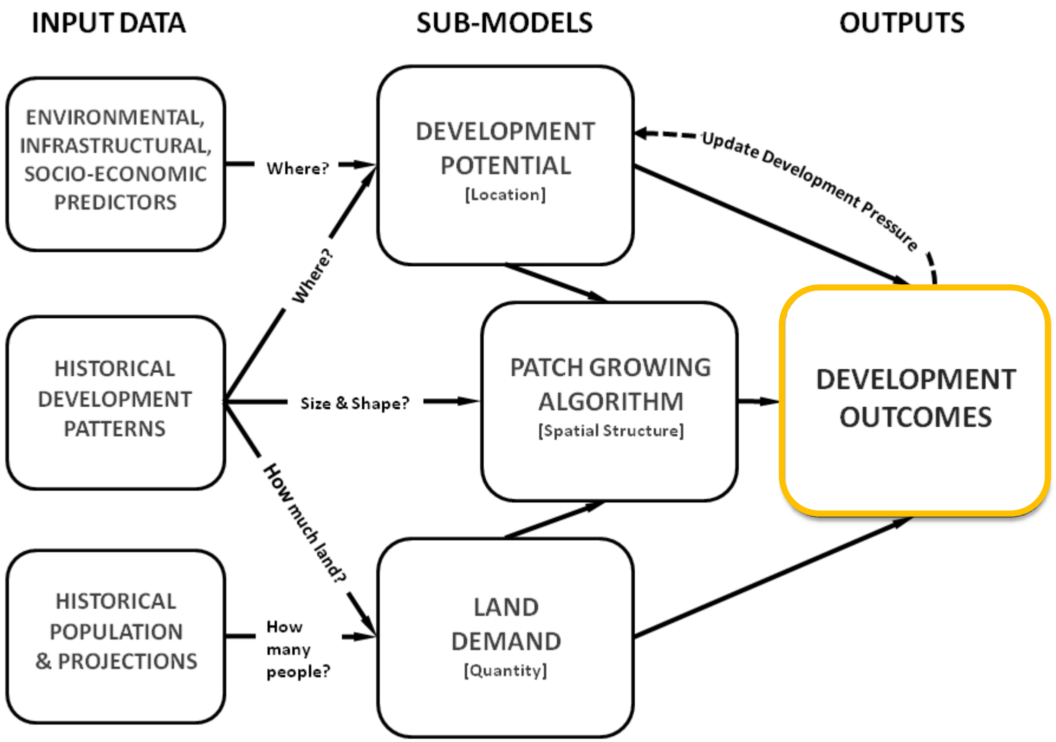
FUTURES

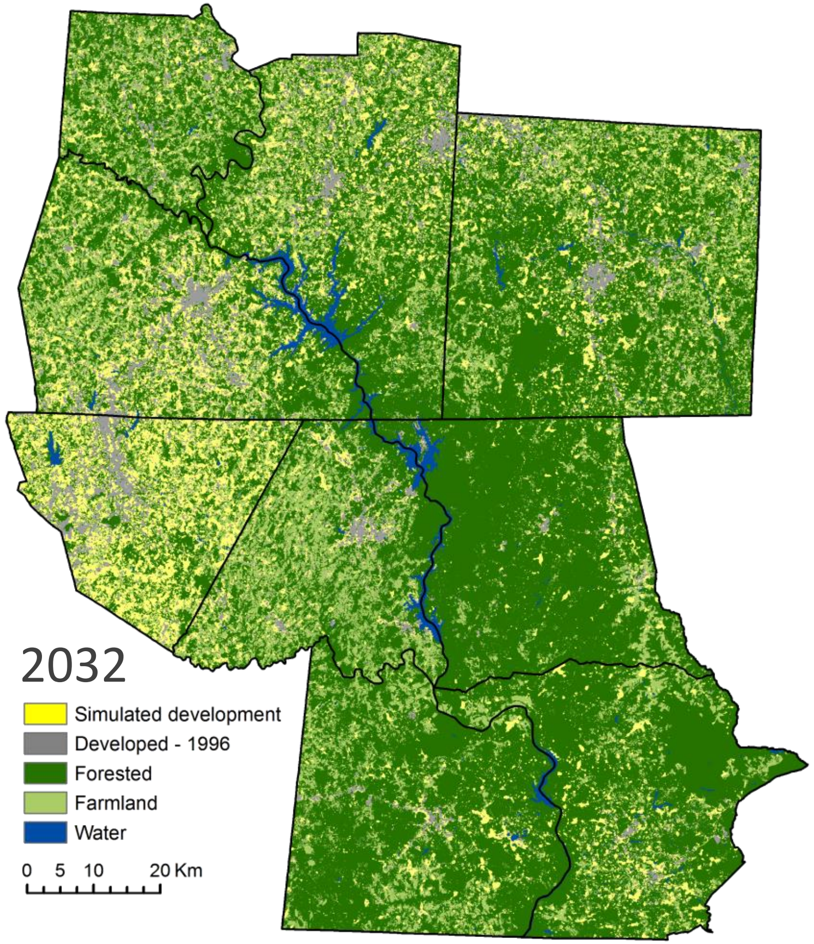

INPUT DATA
SUB-MODELS
OUTPUTS
ENVIRONMENTAL, INFRASTRUCTURAL, SOCIO-ECONOMIC PREDICTORS
Where?
DEVELOPMENT POTENTIAL [Location]
Update Development Pressure
Where?
HISTORICAL DEVELOPMENT PATTERNS
Size & Shape?
PATCH GROWING ALGORITHM [Spatial Structure]
DEVELOPMENT OUTCOMES
How much land?
HISTORICAL POPULATION & PROJECTIONS
How many people?
LAND DEMAND [Quantity]

PGA

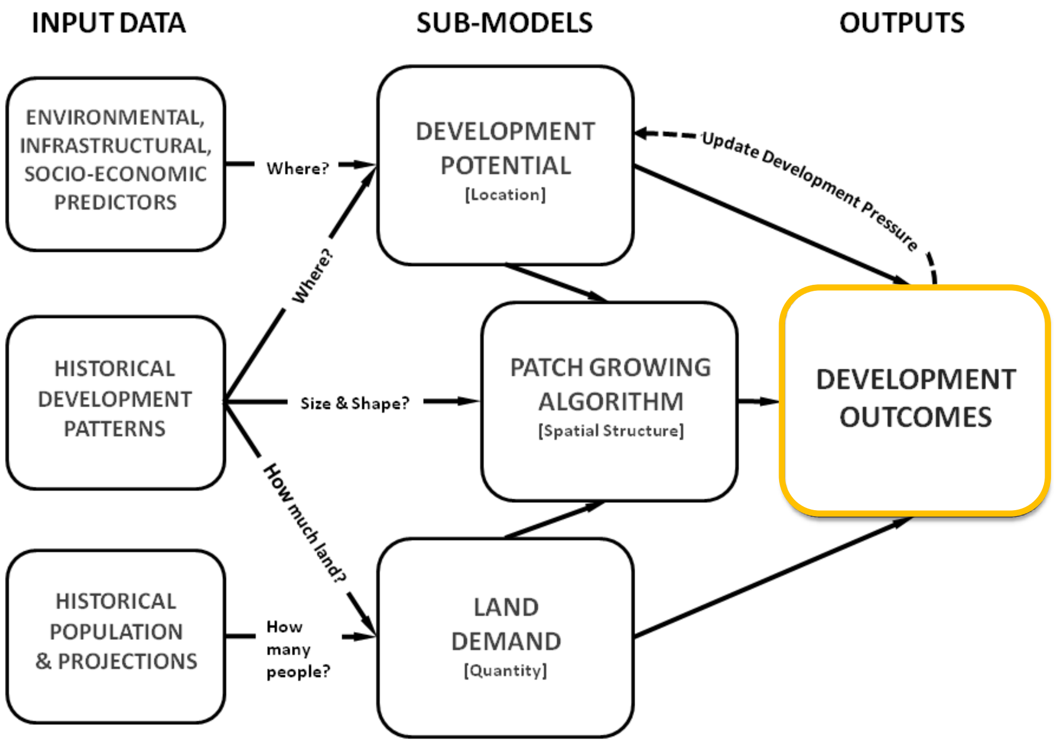

30%
25%
20%
15%
10%
5%
0%
0
9
18
27
36
45
Observed
Simulated
Patch Size (ha)
35%
30%
25%
20%
15%
10%
5%
0%
1
1.5
2
2.5
3
3.5
4
4.5
5
Observed
Simulated
Simple
Patch Shape
Complex

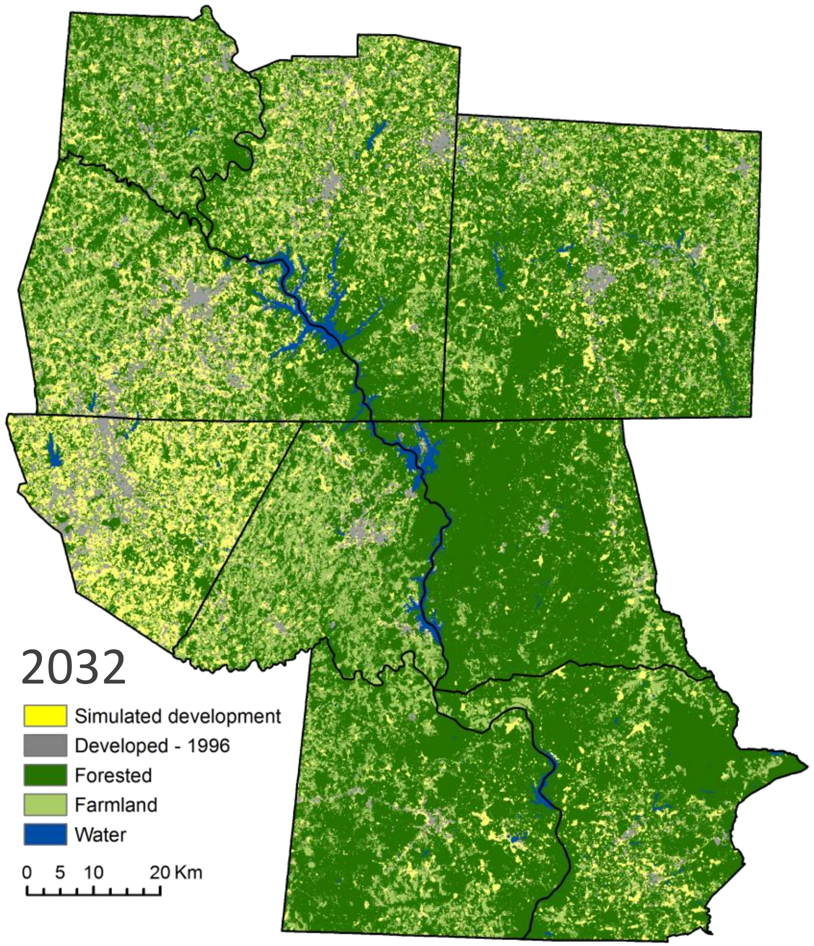
FUTURES


INPUT DATA
SUB-MODELS
OUTPUTS
ENVIRONMENTAL, INFRASTRUCTURAL, SOCIO-ECONOMIC PREDICTORS
HISTORICAL DEVELOPMENT PATTERNS
HISTORICAL POPULATION & PROJECTIONS
Where?
Where?
Size & Shape?
How much land?
How many people?
DEVELOPMENT POTENTIAL [Location]
PATCH GROWING ALGORITHM [Spatial Structure]
LAND DEMAND [Quantity]
Update Development Pressure
DEVELOPMENT OUTCOMES

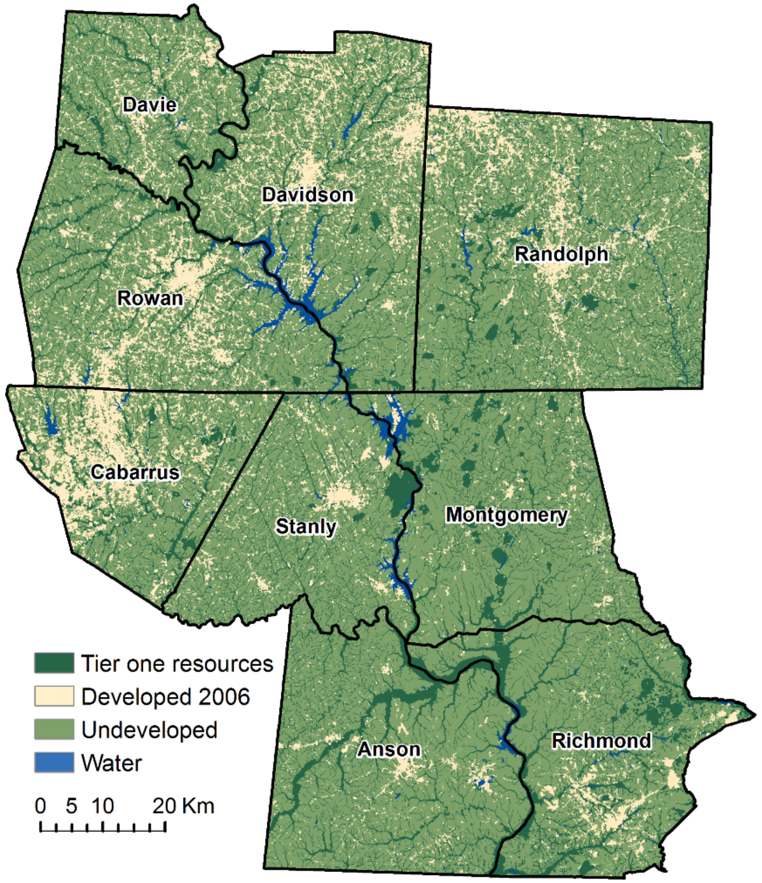

2032
Simulated development
Developed - 1996
Forested
Farmland
Water
0 5 10 20 Km

Scenario 1. Status Quo Growth



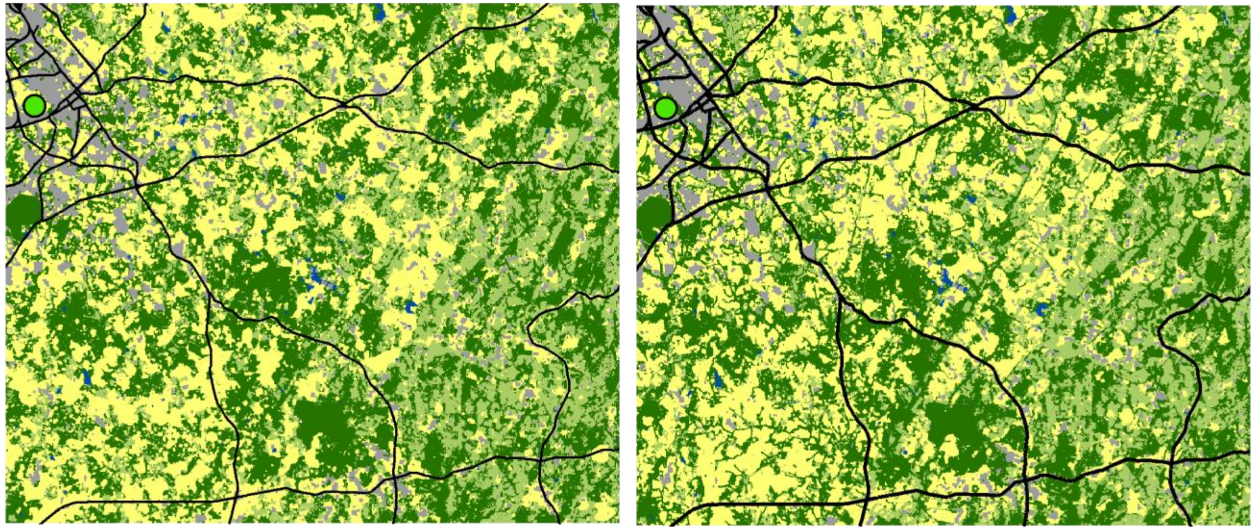


Scenario 2. Development Exclusion

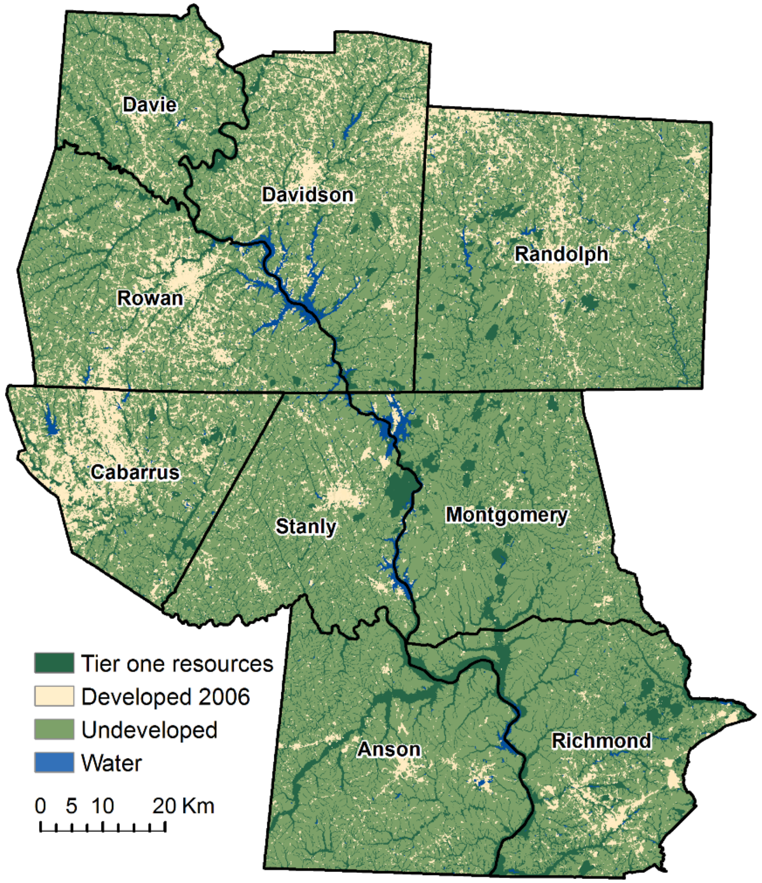


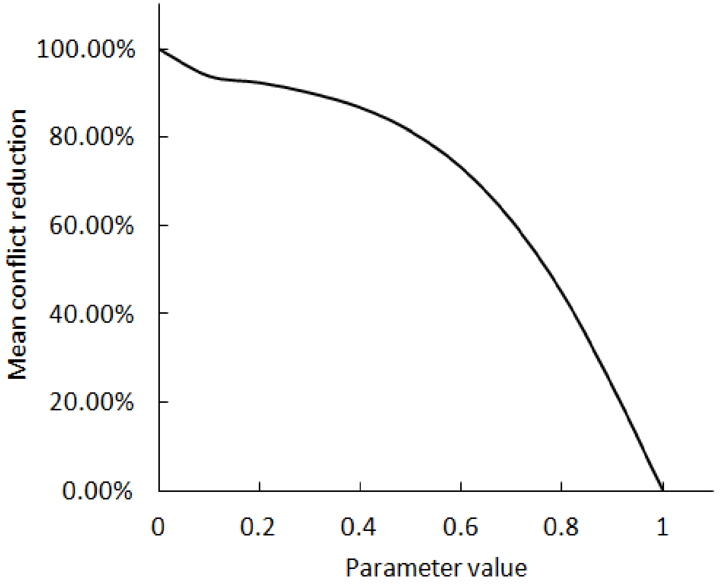
Status Quo

Development Exclusion



Scenario 3. Development Constraint





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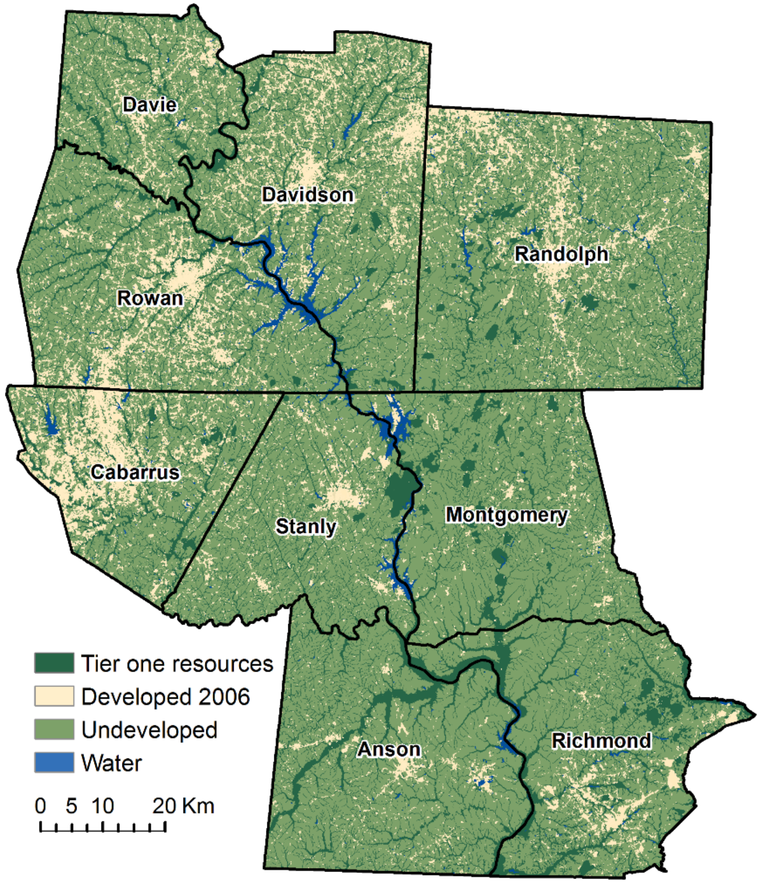
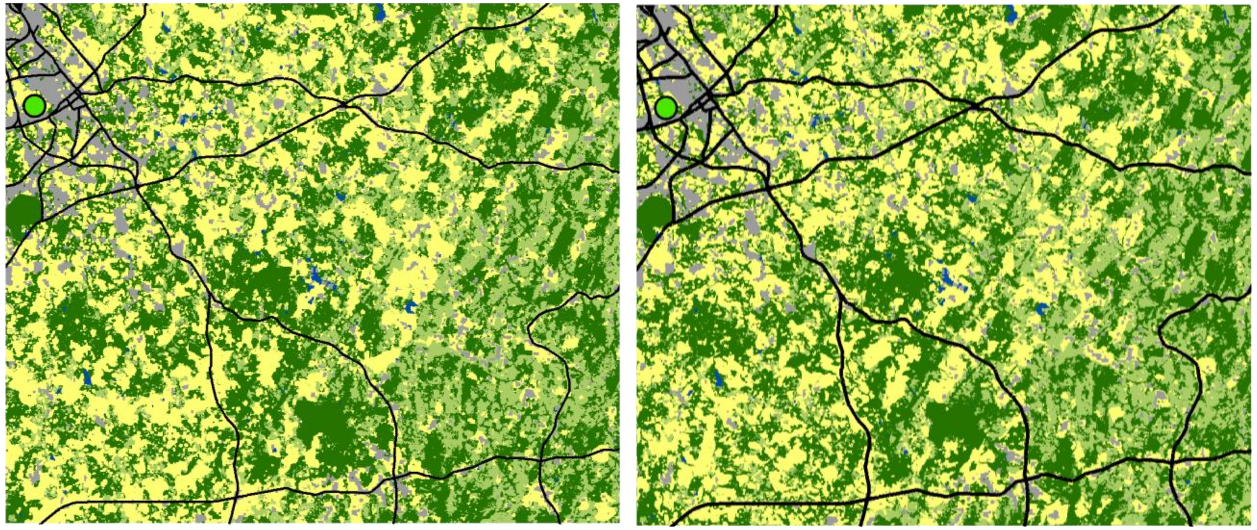
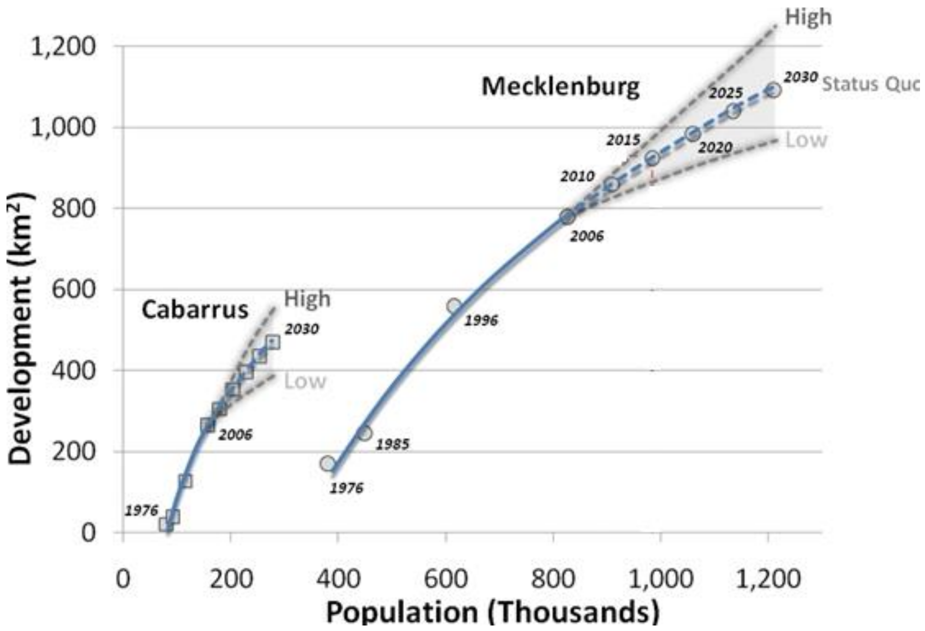


Status Quo

Development Constraint

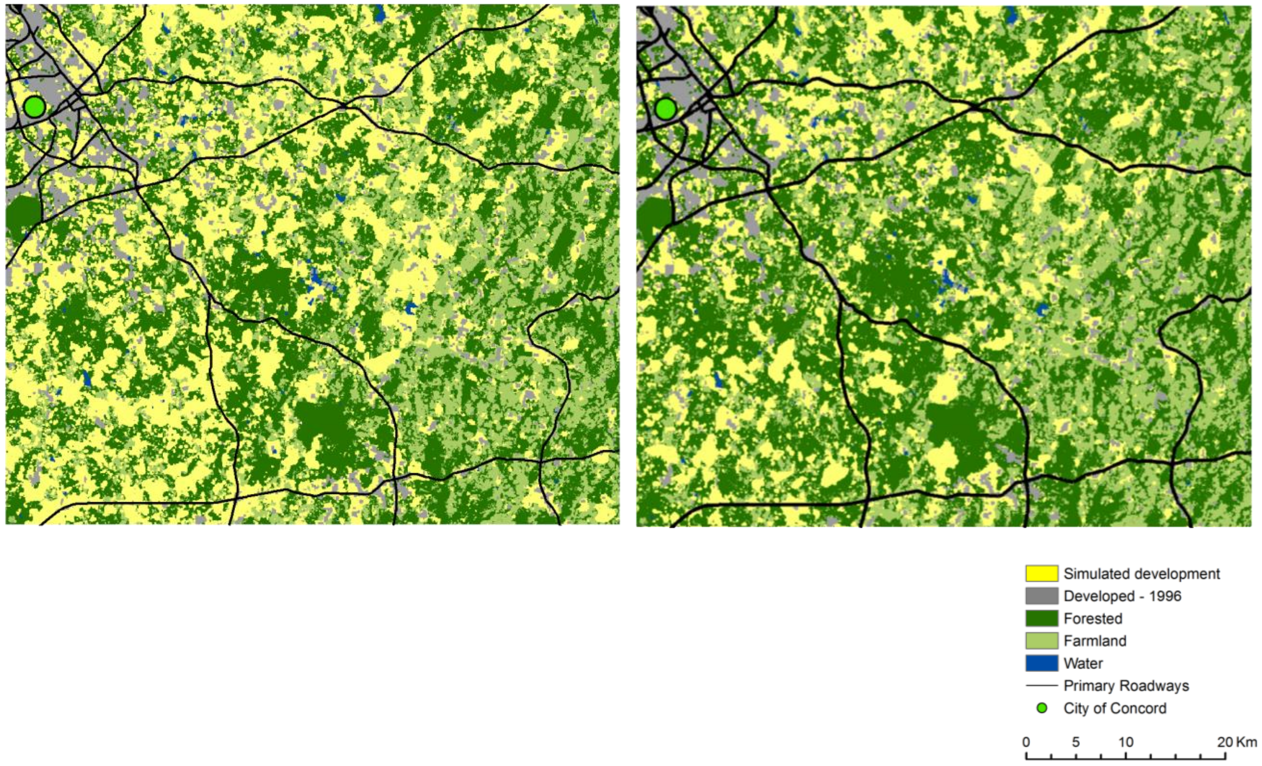


Scenario 4. Reduced Demand

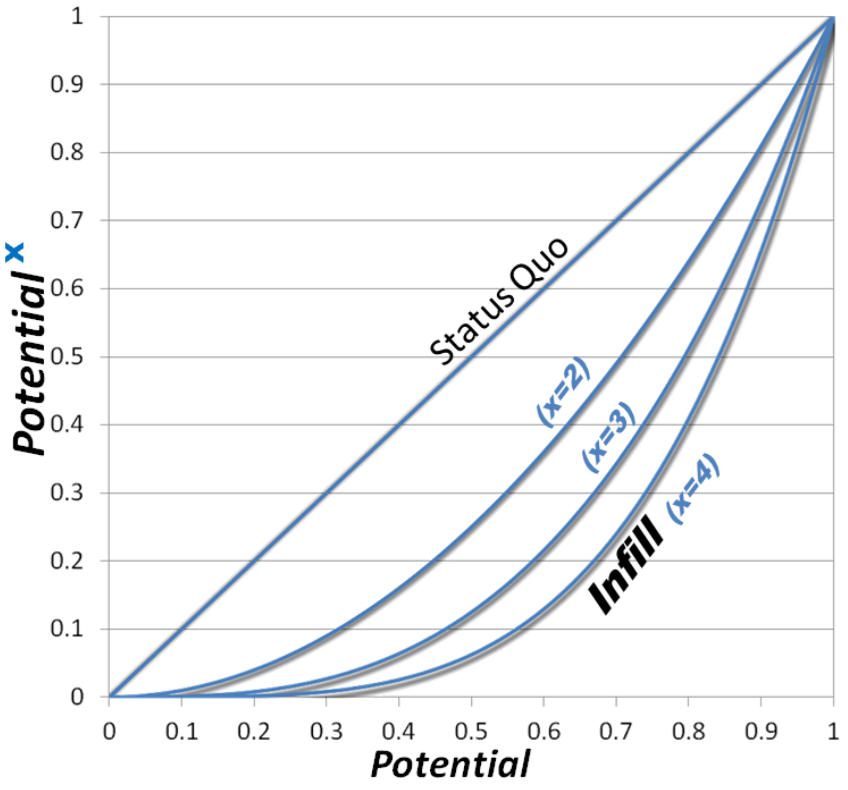


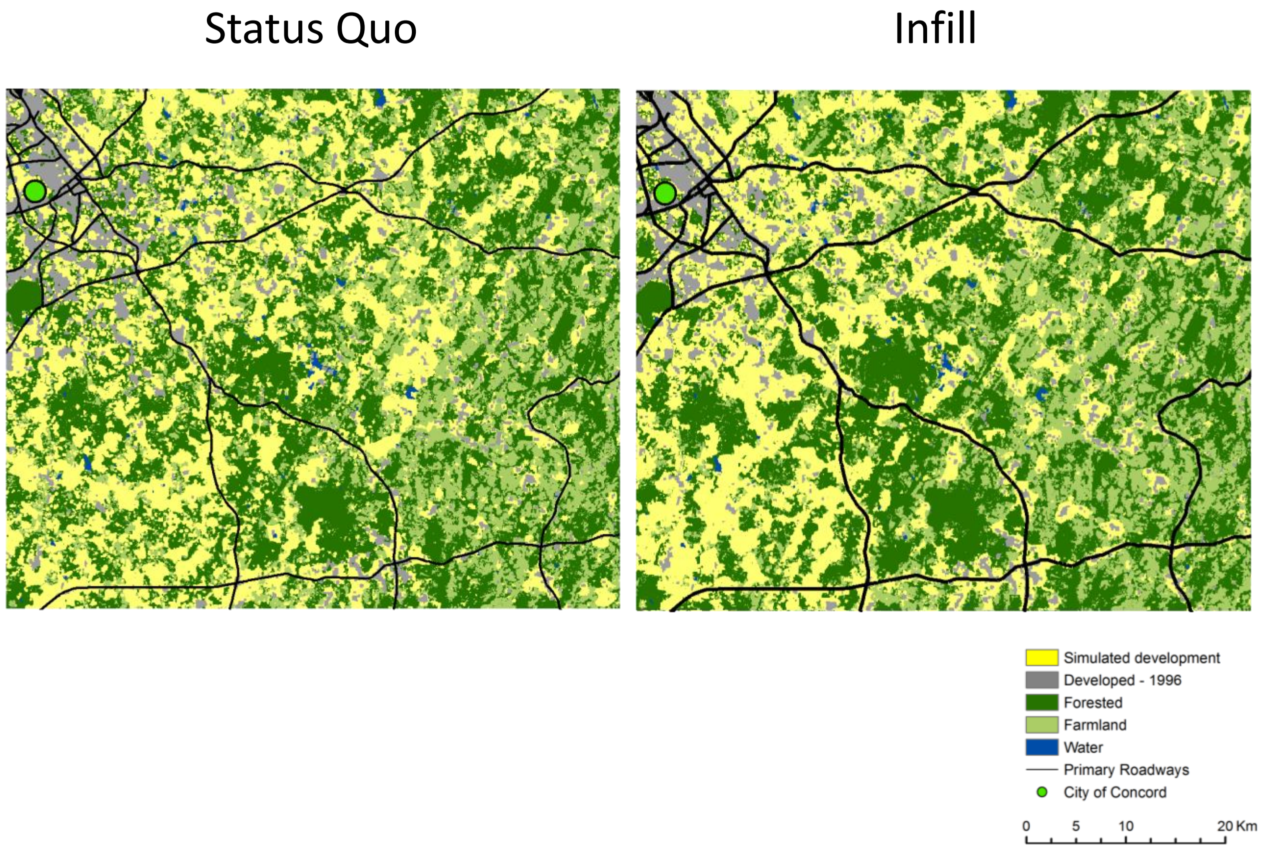
Status Quo

Reduced Demand



Scenario 5. Infill Development



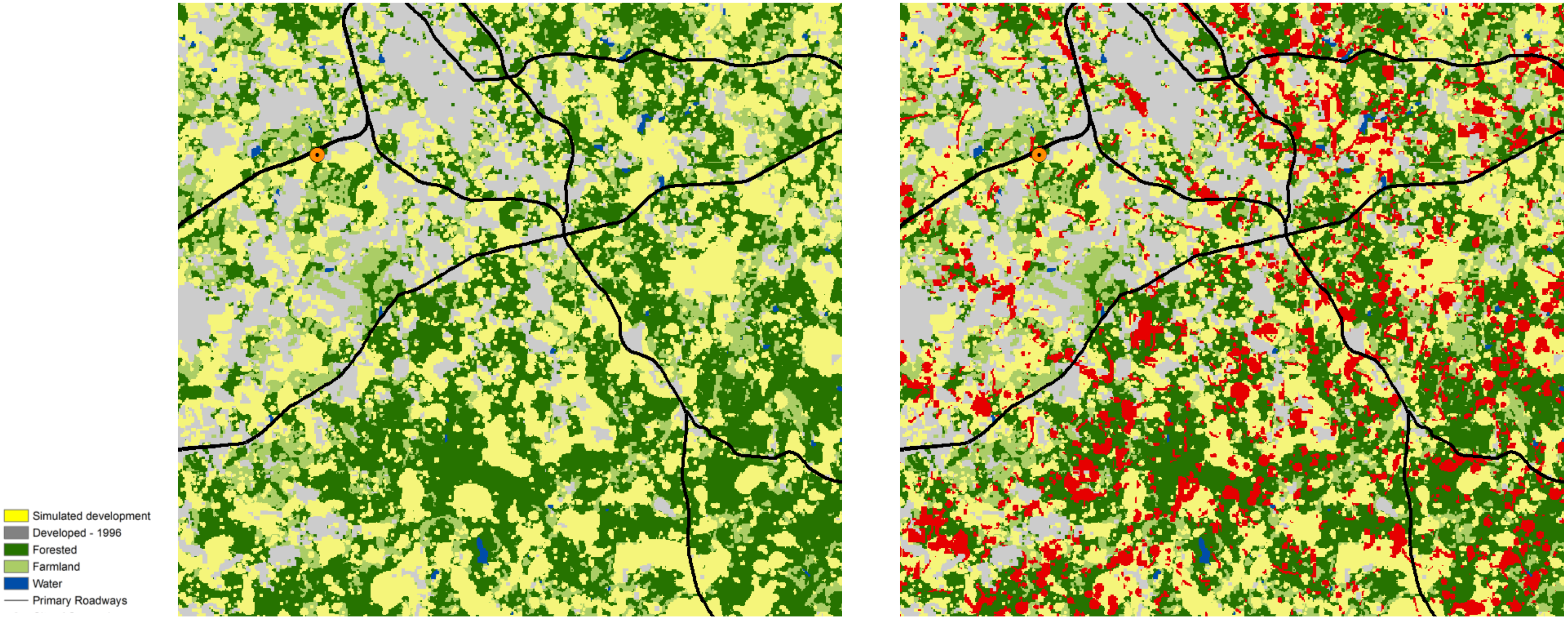


Scenarios 6-9

6. Reduced Demand + Infill
7. Reduced Demand + Development Constraint
8. Infill + Development Constraint
9. Reduced Demand + Infill + Development Constraint

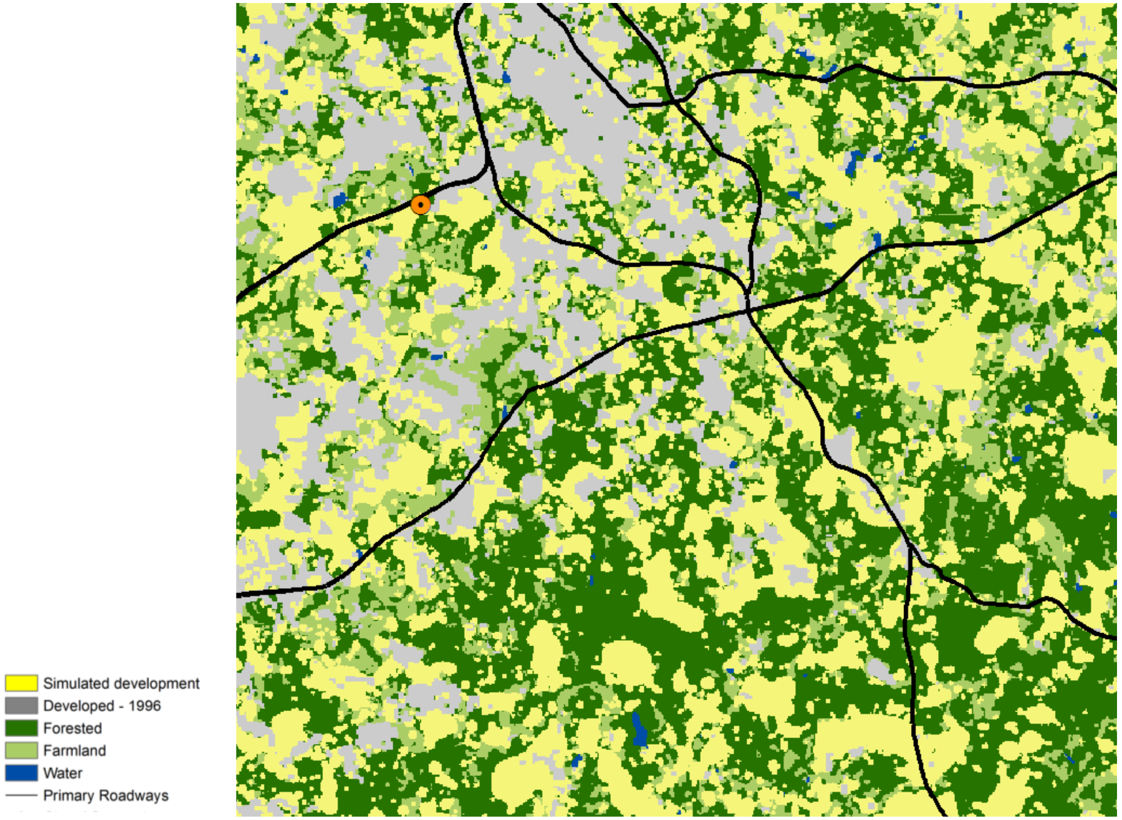
Analyze Outcomes

1. Conflicts: Impacts to priority resources



Analyze Outcomes

2. Patterns: Impacts to forest and farmland



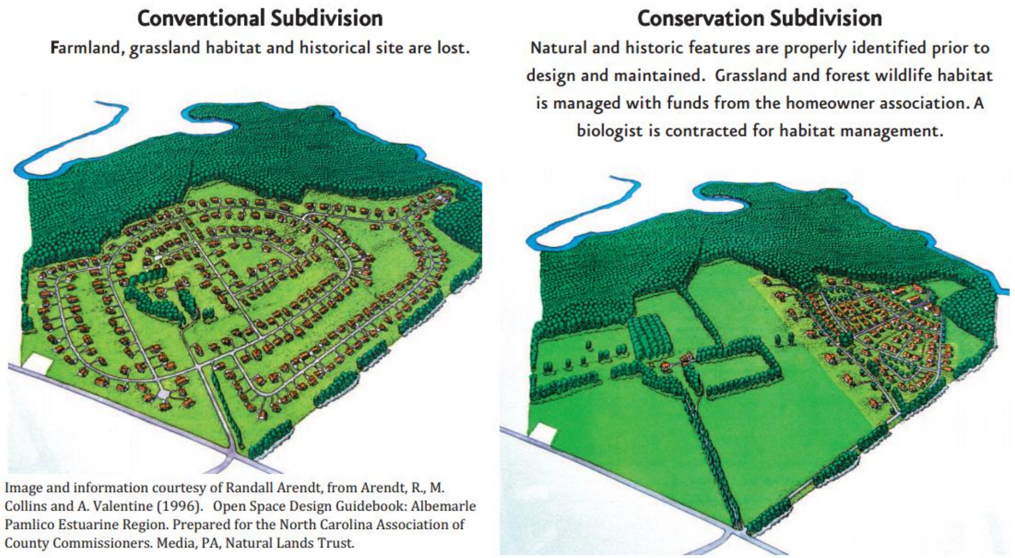


Image and information courtesy of Randall Arendt, from Arendt, R., M. Collins and A. Valentine (1996). Open Space Design Guidebook: Albemarle Pamlico Estuarine Region. Prepared for the North Carolina Association of County Commissioners. Media, PA, Natural Lands Trust.

Analyze Outcomes

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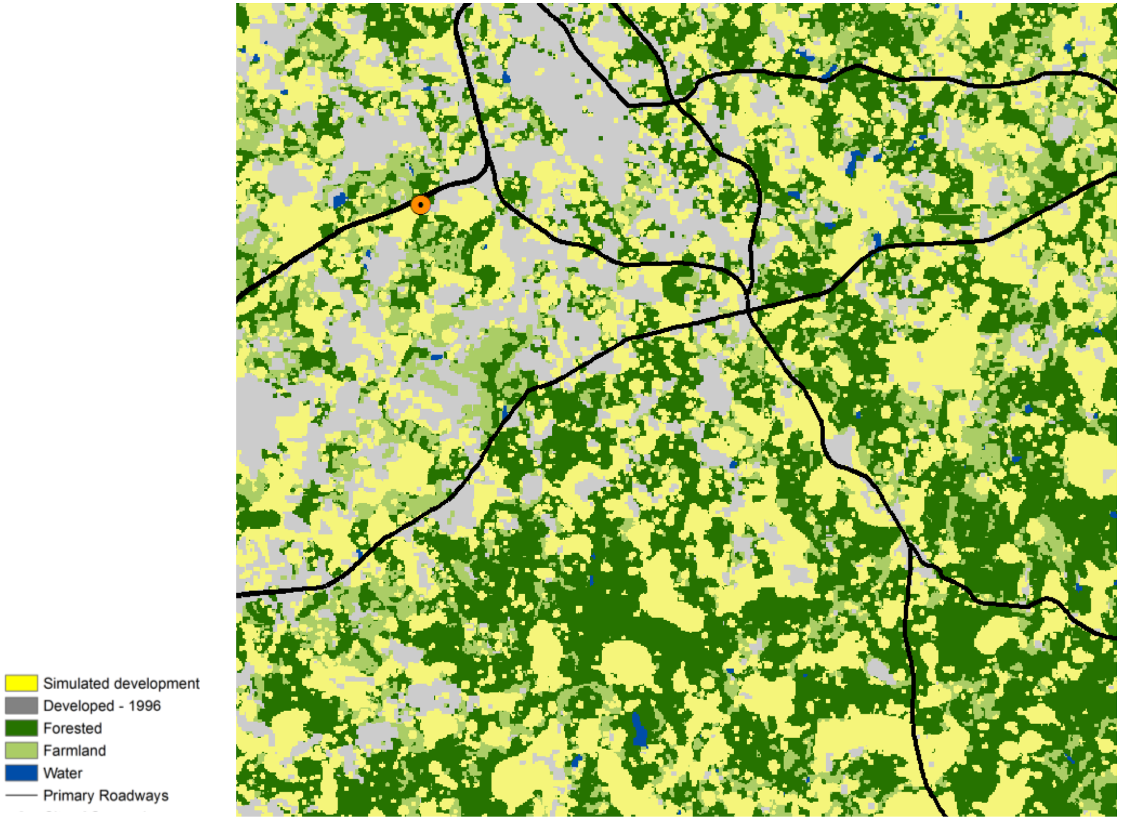
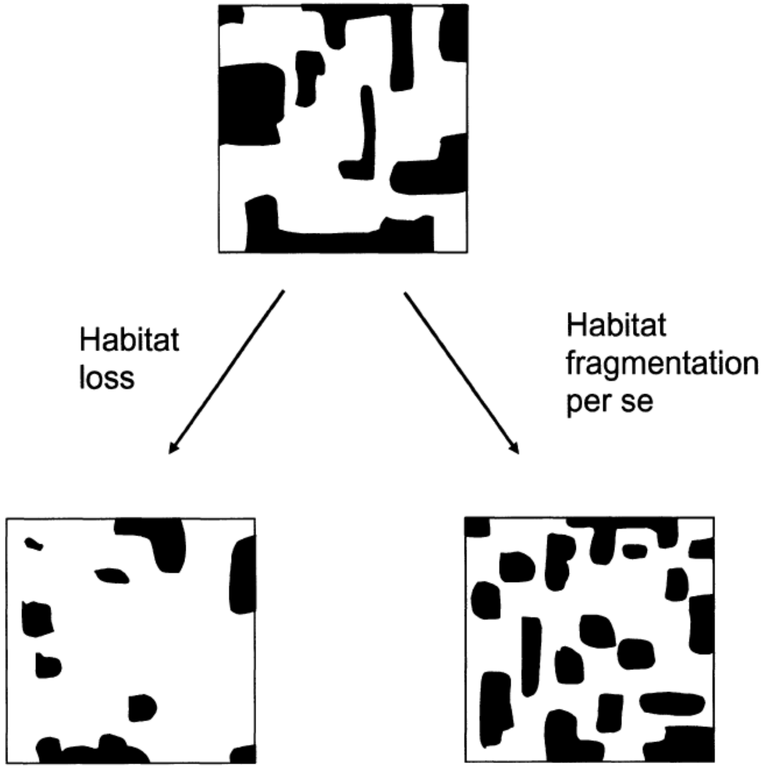
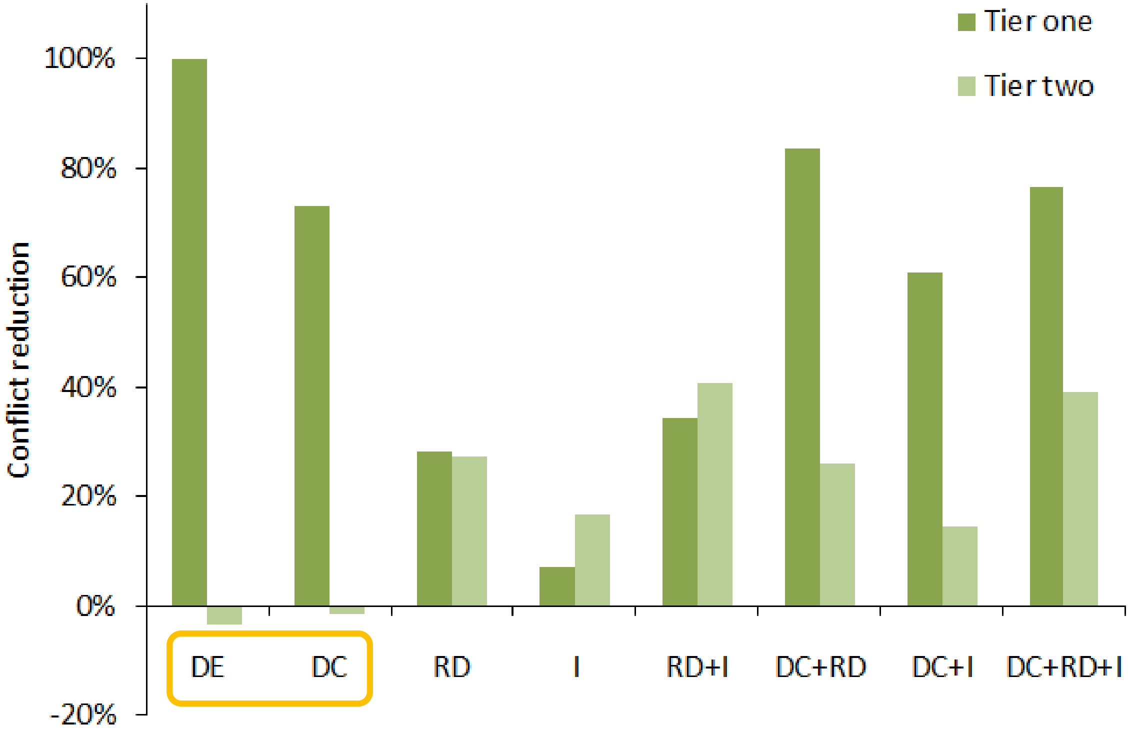




Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics 34: 487-515.

Conflicts

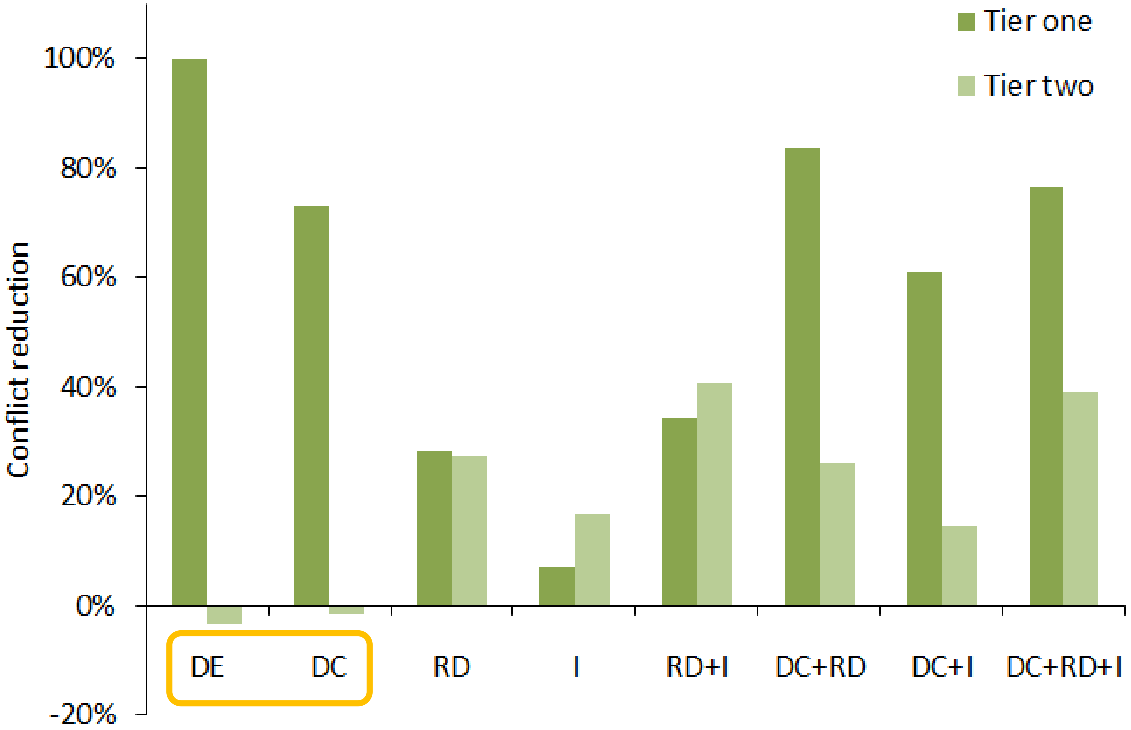


DE = Development exclusion
DC = Development constraint

RD = Reduced demand
I = Infill

Conflicts

Patterns



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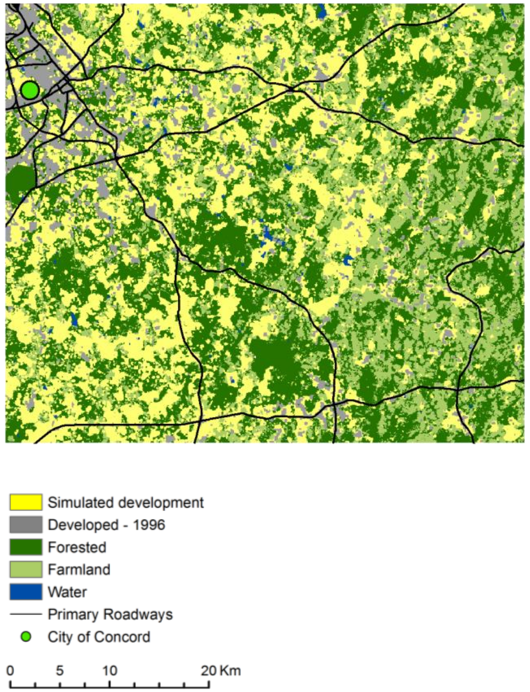
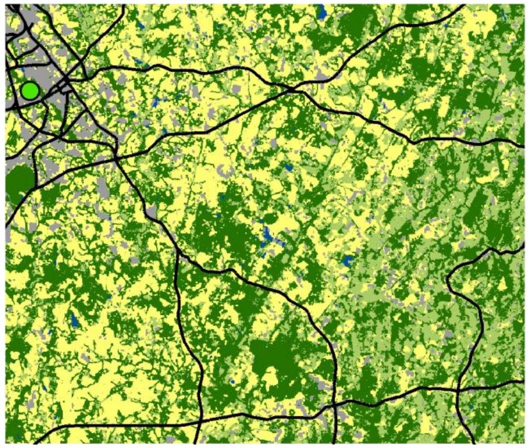
Status Quo

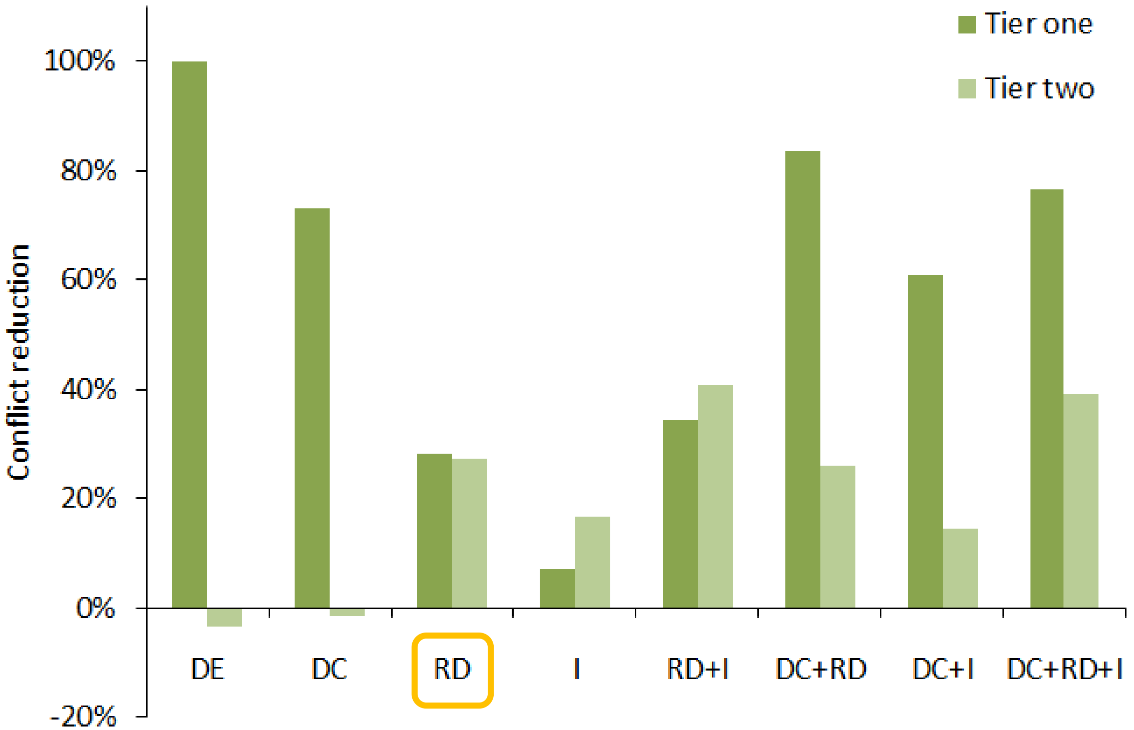


Development Exclusion



More fragmentation
- -same area forest and farmland
- -more patches
- -smaller patches

Conflicts



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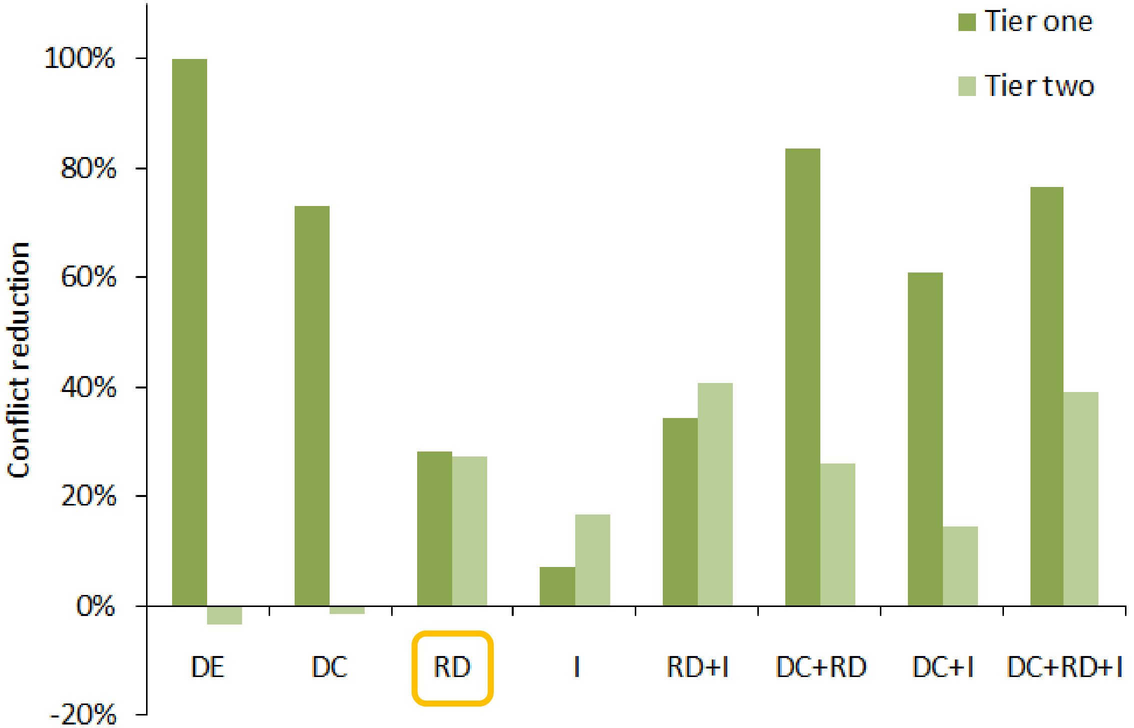
Conflicts

Patterns



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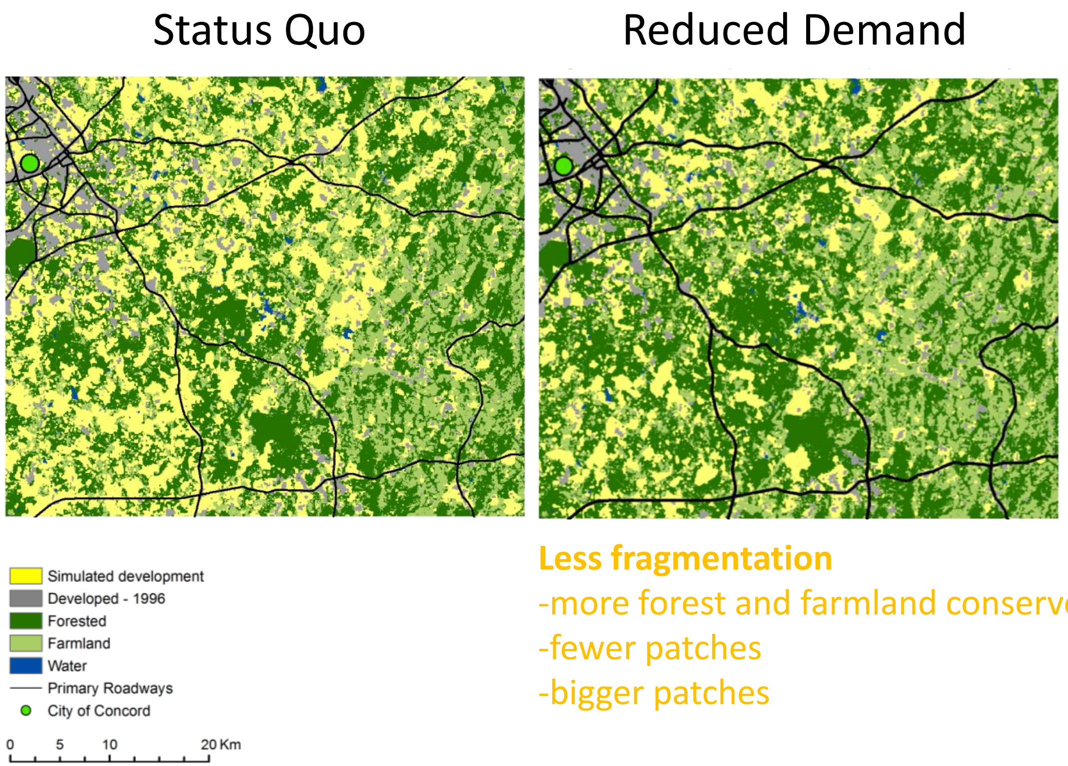


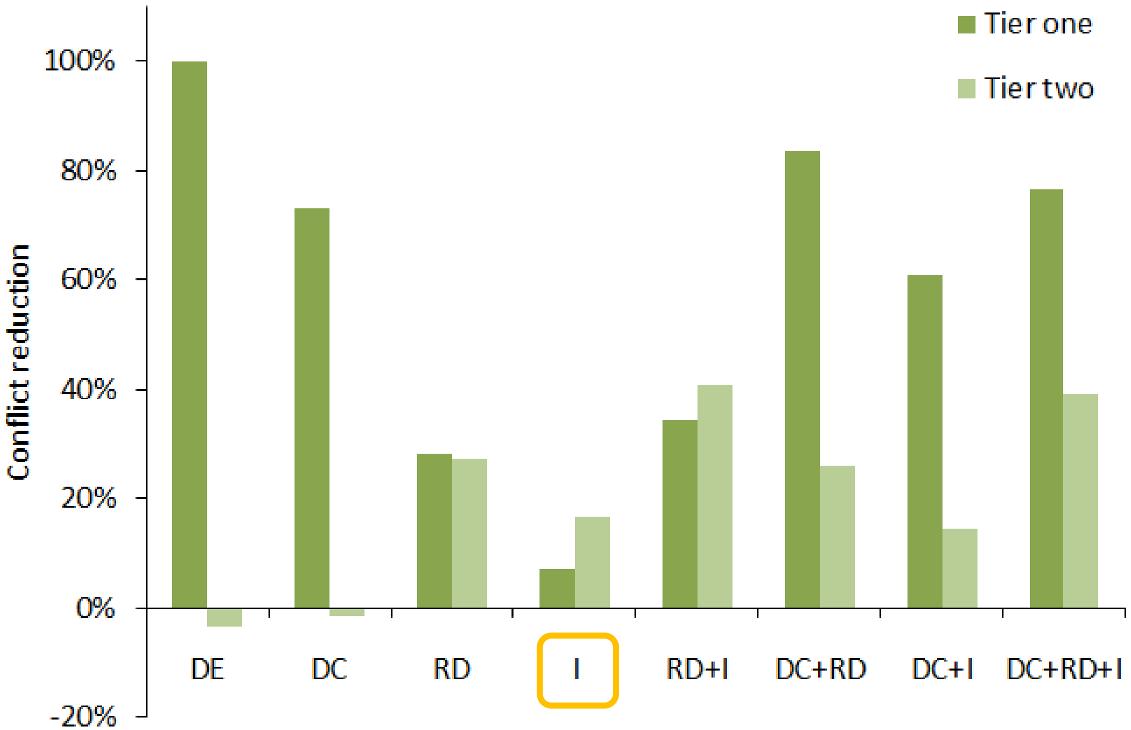
Less fragmentation

-more forest and farmland conserved

-fewer patches

-bigger patches

Conflicts



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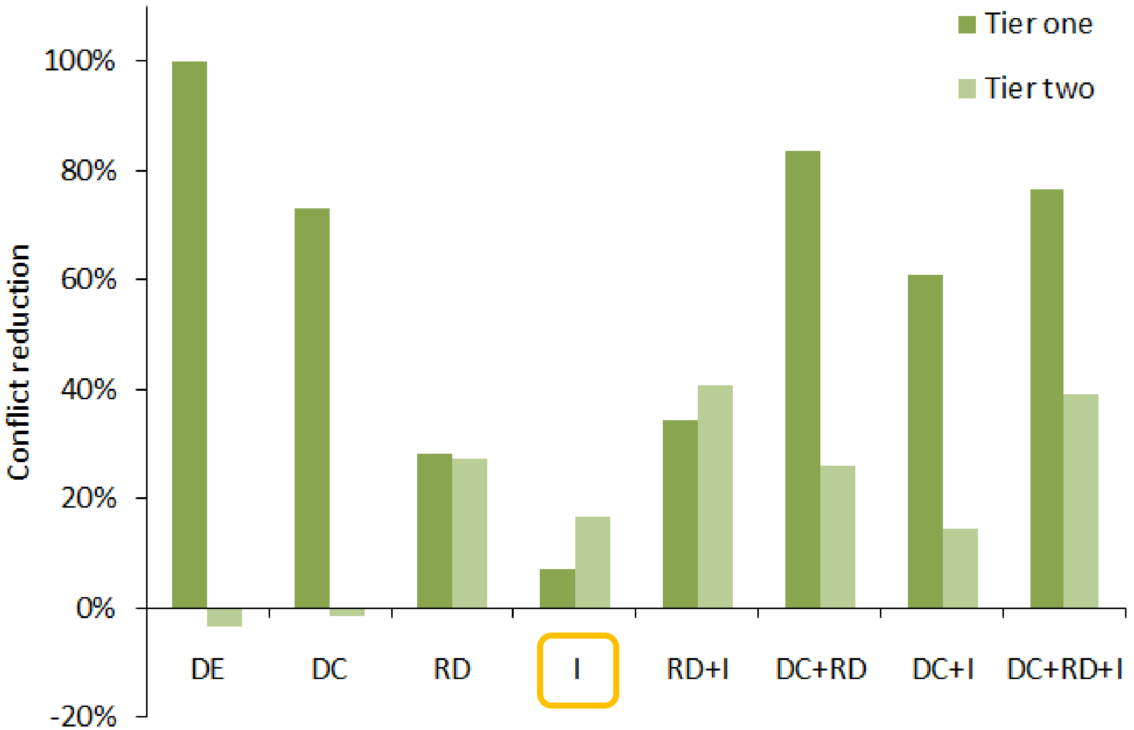

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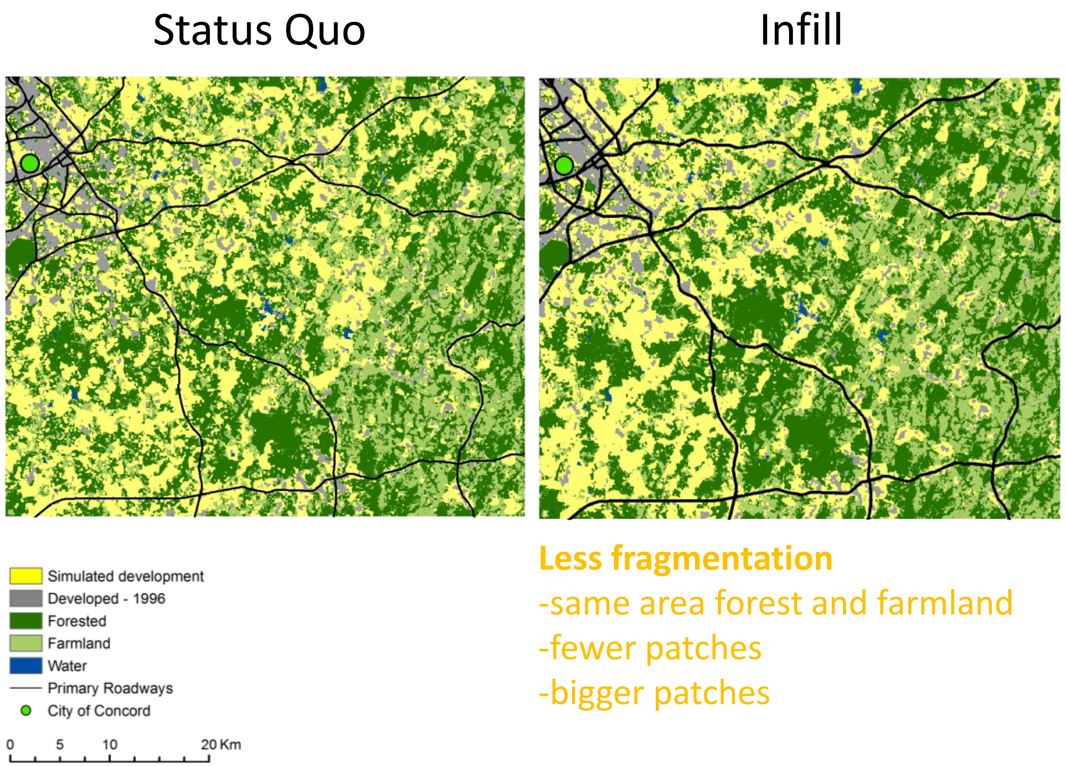

Less fragmentation

-same area forest and farmland
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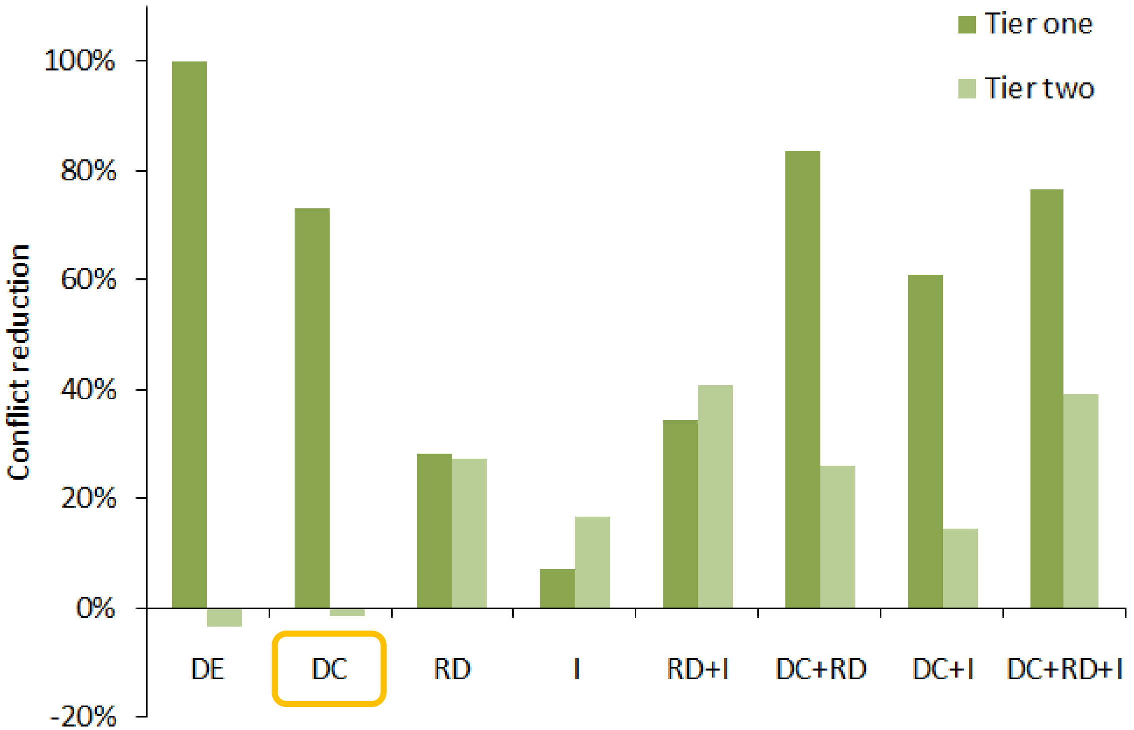
-bigger patches

Competing Policies



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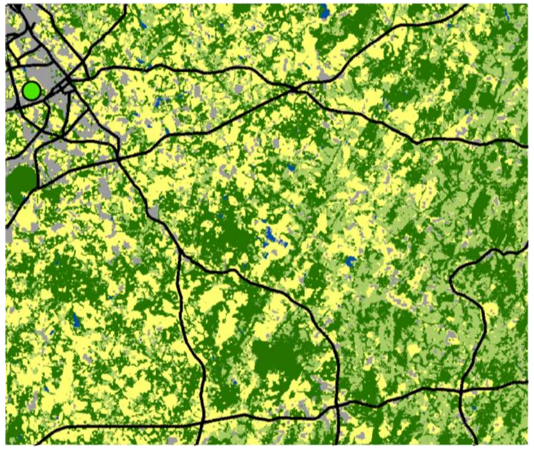
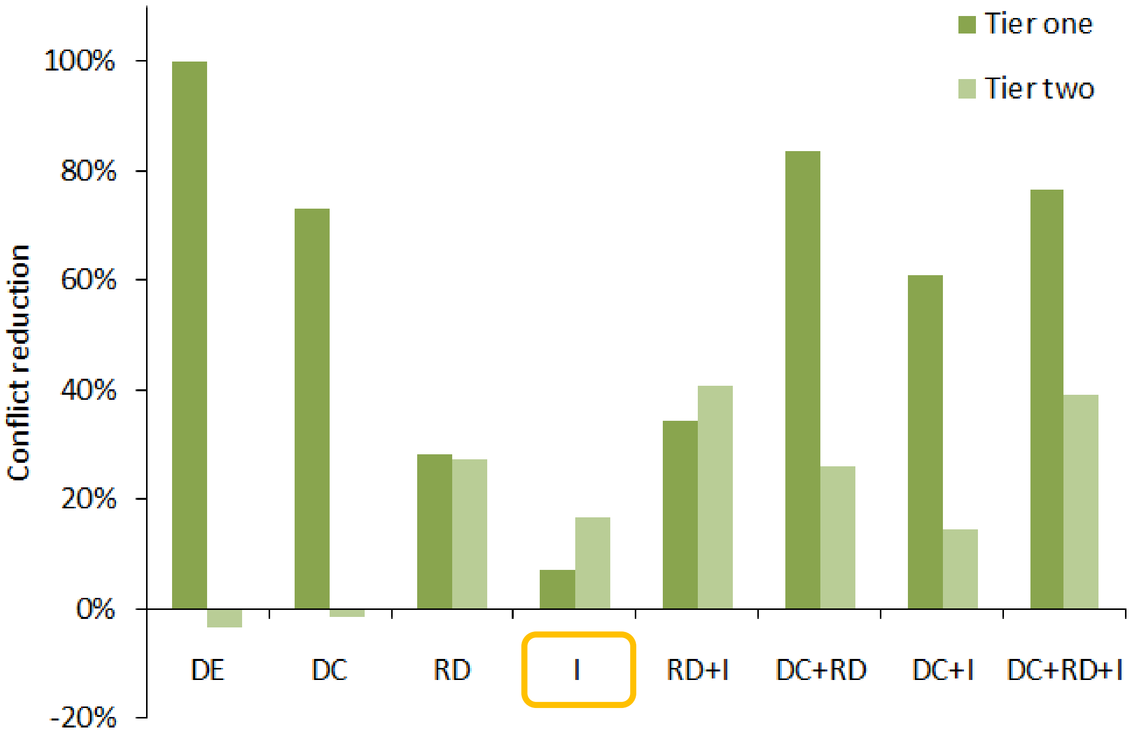
Development Constraint



More fragmentation

Competing Policies



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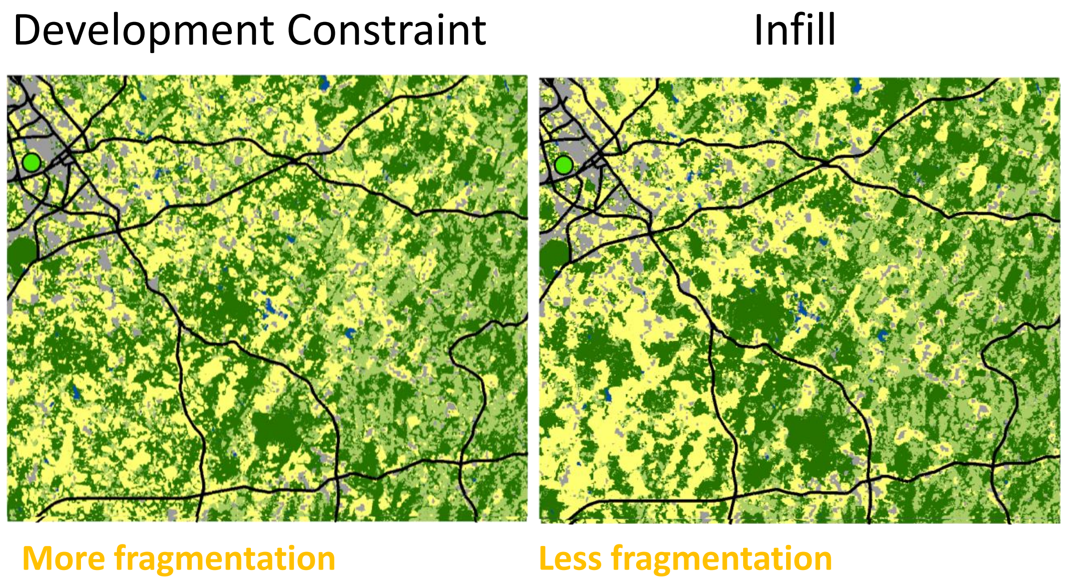
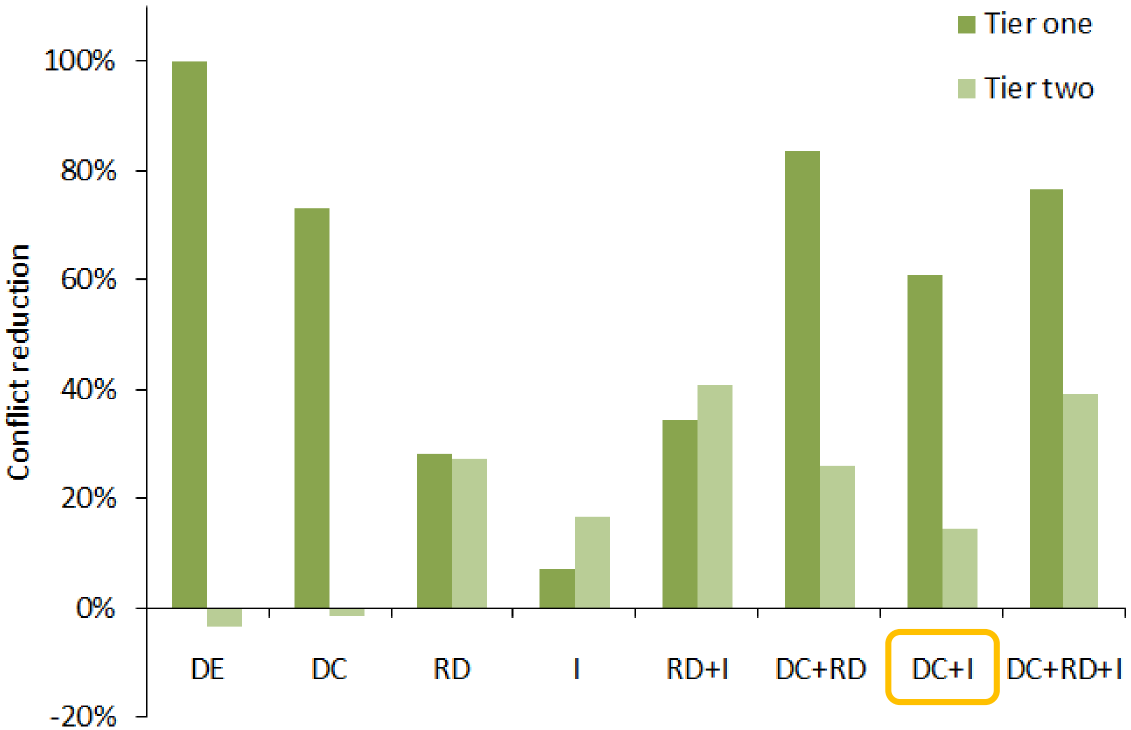


Competing Policies



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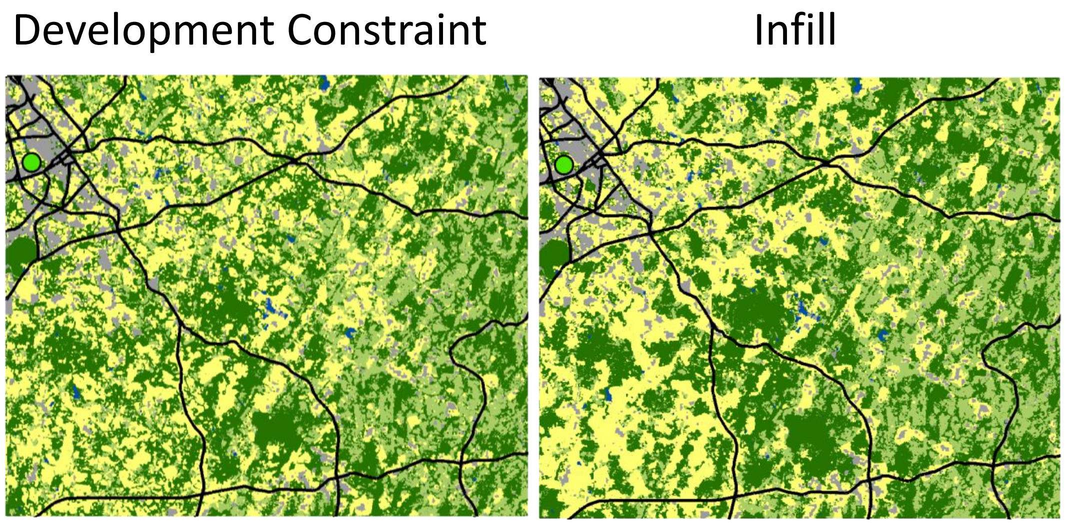


More fragmentation

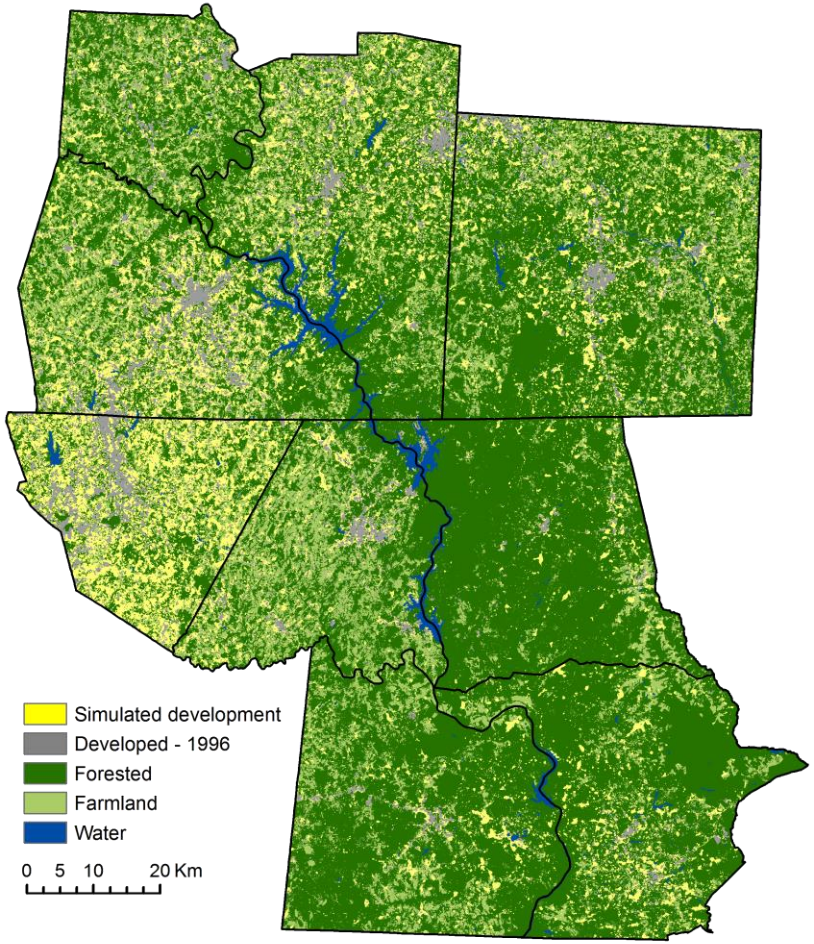
Less fragmentation

Less fragmentation than Development Constraint
More fragmentation than Infill

Conclusions

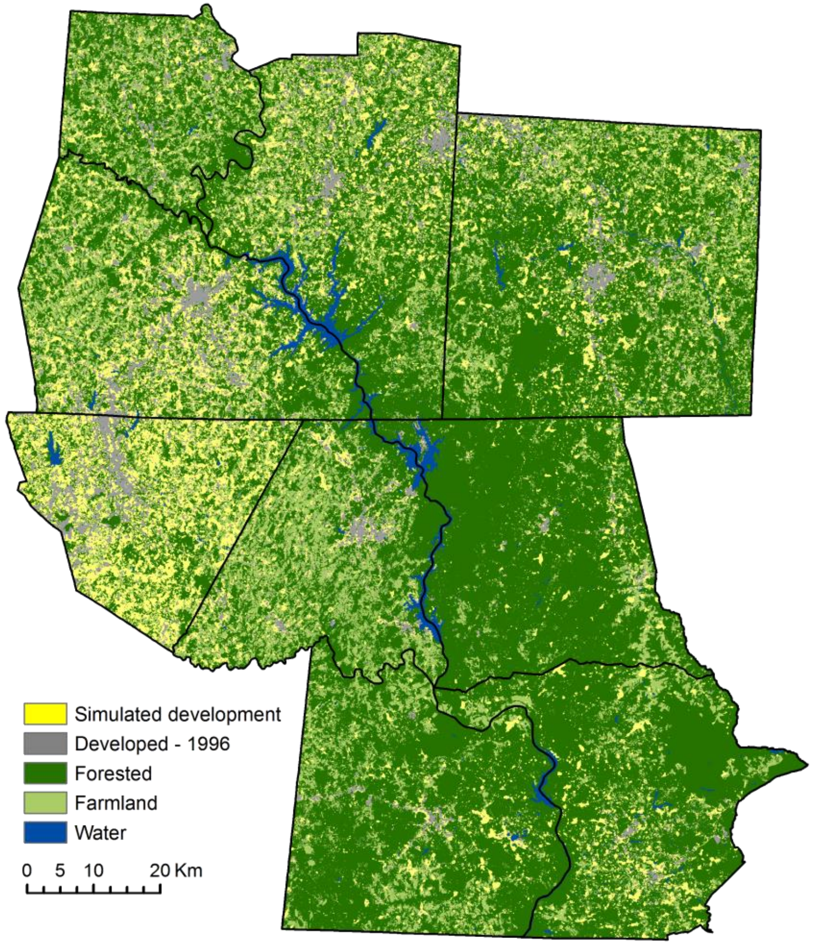
- Explored urbanization scenarios based on hypothetical land use policies
- Used unique modeling method to represent conservation planning strategies
- No single strategy was best for achieving all conservation goals
- Effective planning requires assessment of tradeoffs between different priorities

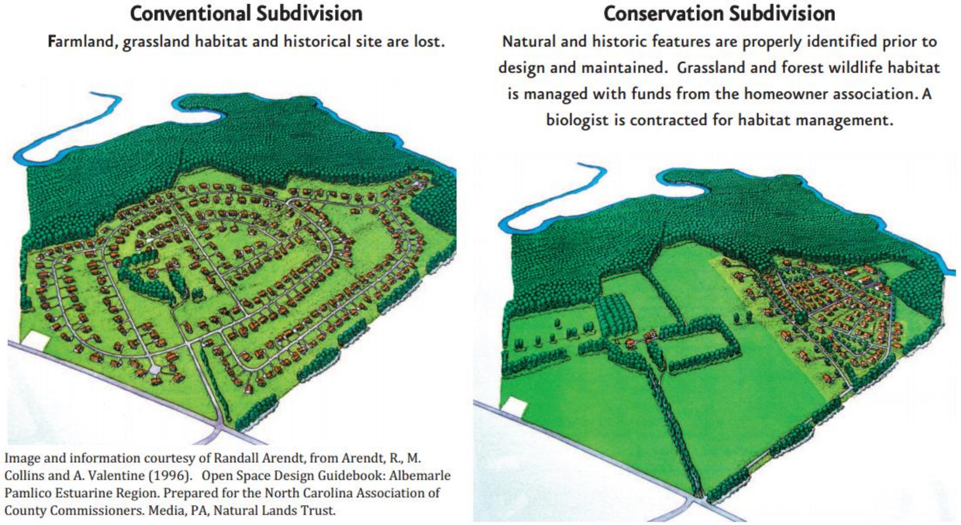
Applications and Limitations



NORTH CAROLINA Wildlife RESOURCES COMMISSION

Applications and Limitations





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Thank You!

Jennifer Koch – jakoch@ou.edu

Geography and Environmental Sustainability

The University of Oklahoma

Monica Dorning, Ross Meentemeyer, Doug Shoemaker

Center for Geospatial Analytics

North Carolina State University

FUTURES Performance

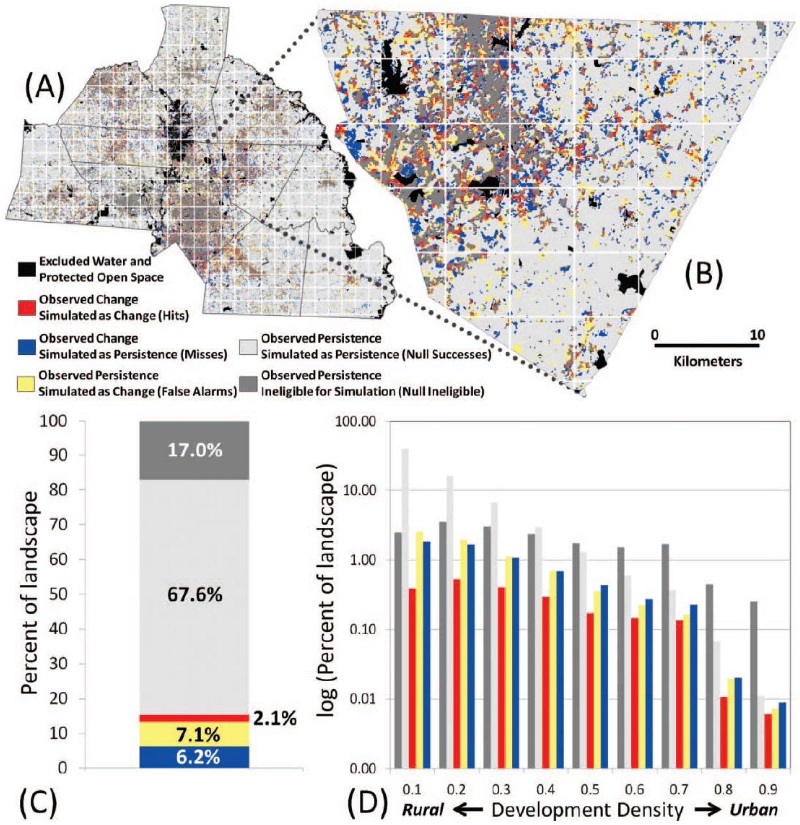

Figure 5. Cell-level model performance based on simulation successes and errors across study system. (A) Spatial distribution of successes and errors comparing 1996–2006 observed and simulated change. The 6 × 6 km lattice (white grid) used to analyze successes and errors by block and along development density gradient. (B) Successes and errors in Cabarrus County. (C) Proportions of successes and errors for entire landscape. (D) Distribution of block-summarized successes and errors along development density gradient (bin interval of 0.1). Map legend also applies to (C) and (D) with the exception of excluded water and protected open space. (Color figure available online.)

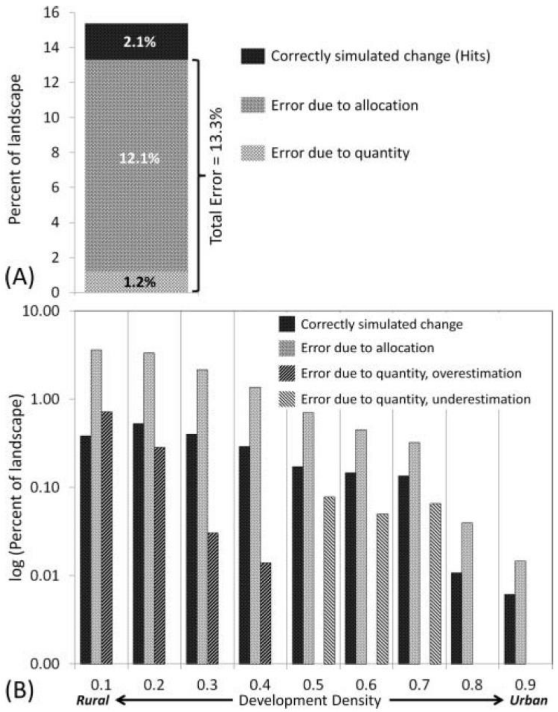

Figure 6. Cell-level model performance based on accuracy of simulated change (1996–2006) across study system. (A) Proportions of errors and correctly simulated change for entire landscape. (B) Distribution of errors and correctly simulated change along development density gradient (bin interval of 0.1). Overestimation indicates false alarms > misses; underestimation indicates false alarms < misses. Missing bars indicate no error in category.

FUTURES Performance

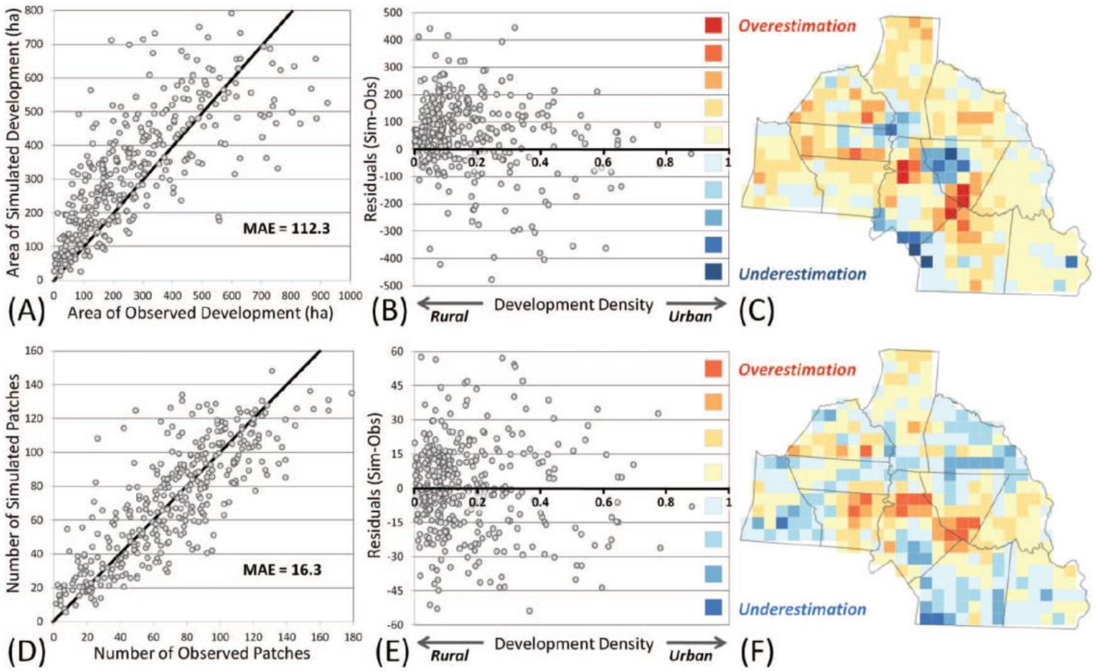

Figure 7. Patch-level model performance comparing 1996–2006 observed and simulated patch area and number of patches, summarized by blocks across study system. (A) Total patch area (ha) of observed and simulated development plotted along one-to-one line and with mean absolute error (MAE) reported. (B) Residuals of total area (ha) of development plotted along development density gradient and (C) spatial distribution of residuals indicate overestimates in North and East Charlotte and rural areas. (D) Number of observed and simulated patches of development plotted along one-to-one line and with MAE reported. (E) Residuals of number of patches of development plotted along development density gradient and (F) spatial distribution of residuals indicate over- and underestimation vary across region with overestimates in transitioning areas of North and East Charlotte. Blocks with > 50 percent of area beyond study system boundary were excluded. (Color figure available online.)