RSim: A Regional Simulation to Explore Impacts of Resource Use and Constraints

SERDP 1259

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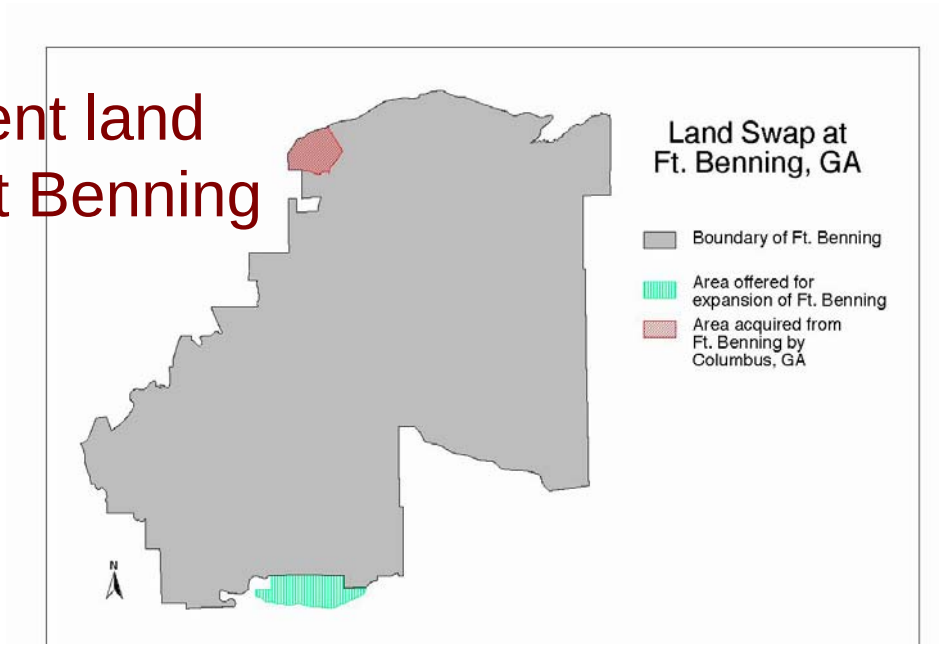
Performers

- Virginia Dale, Oak Ridge National Laboratory -- Habitat modeling and integration of impacts
- Latha Baskaran, Lisa Olsen and Robert Washington-Allen, Oak Ridge National Laboratory -- Geographic information and landscape analysis
- Michael Berry and Matthew Aldridge, University of Tennessee -- Land use modeling and model integration
- Michael Chang, Georgia Tech -- Air quality modeling
- Rebecca Efroymson, Oak Ridge National Laboratory -- Risk analysis
- Chuck Garten and Tom Ashwood, Oak Ridge National Laboratory -- Water quality /nitrogen dynamics
- Catherine Stewart, Aberdeen Proving Ground, U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM)-- Noise modeling

The Problem

- The SERDP Ecosystem Management Workshop (Botkin et al. 1997) called for focus on the health of a region.
- The theory and tools for understanding regional ecological interactions are poor
  - Unclear how activities in region constrain military training and testing
  - Unclear how activities on base influence regional environmental conditions
  - Land swaps can alter environmental conditions of region

Sites of recent land swap at Fort Benning



Research need: Understanding cumulative impacts

- Under what conditions do human activities combine to cause greater effects on the environment?

Effects of Atlanta air pollution vs controlled fire for long leaf pine habitat

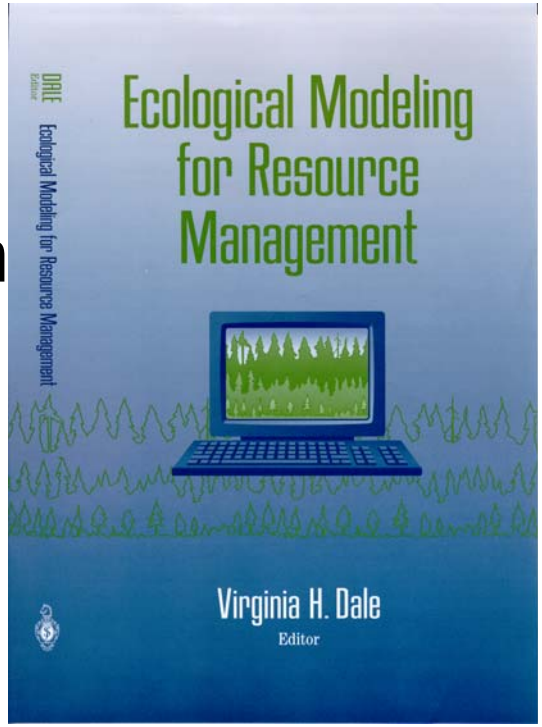
*Habitat

*Air quality

Dateline: Columbus, GA, August 18, 2000
Columbus violated federal air quality standards Thursday for the second time this year after a record high of 102 degrees combined with haze from a controlled burn at Fort Benning, a state air quality official said.

Technical Background

- DoD and other agencies have supported data analysis and development of models for:
  - Noise
  - Air quality
  - Nutrient dynamics and water quality
  - Endangered species habitat
- The Ecosystem Management approach is endorsed; yet there is no mechanism for integrating the various components
- "Ecological Modeling for Resource Management" calls for models to improve decision making



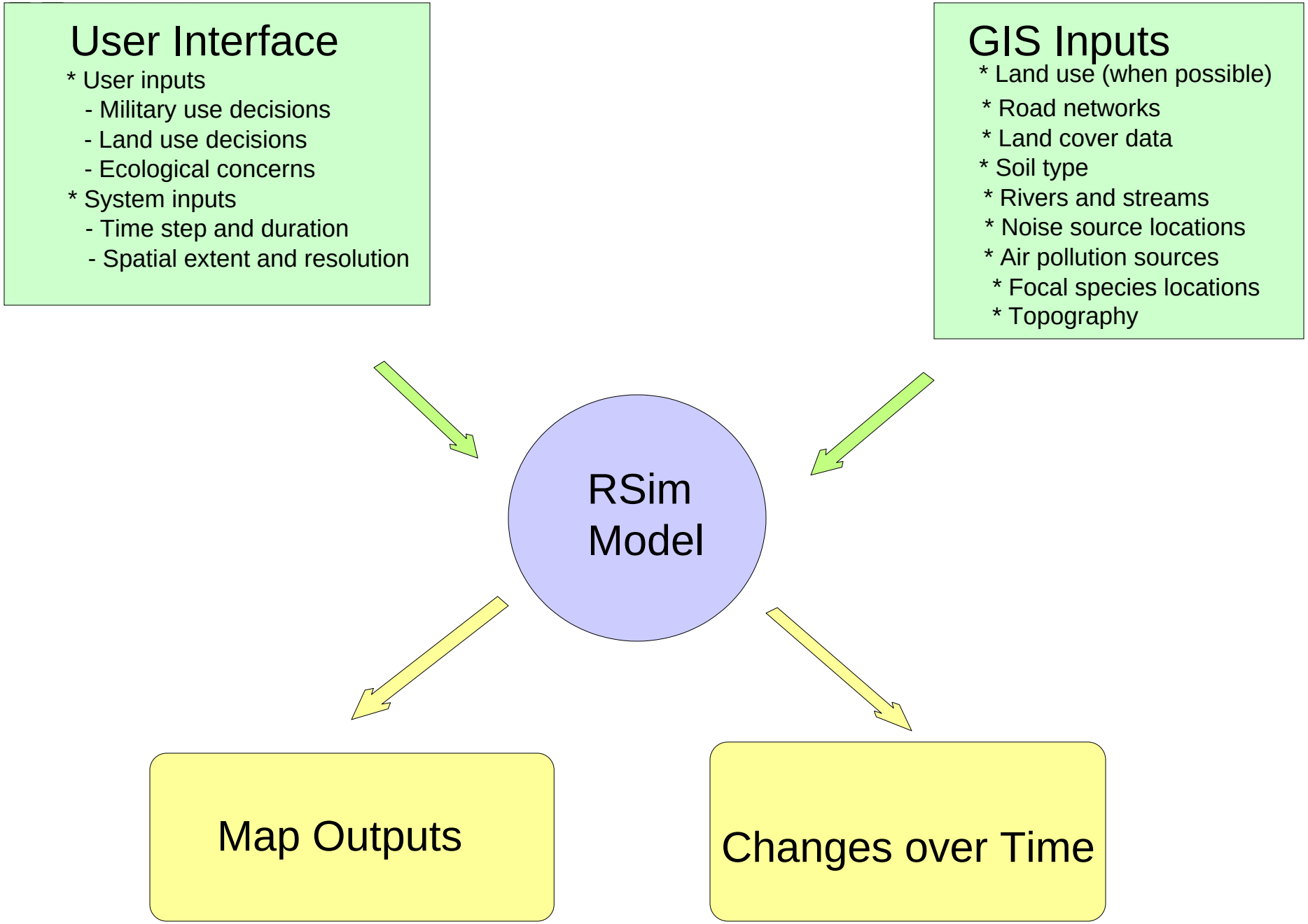
Technical Objective

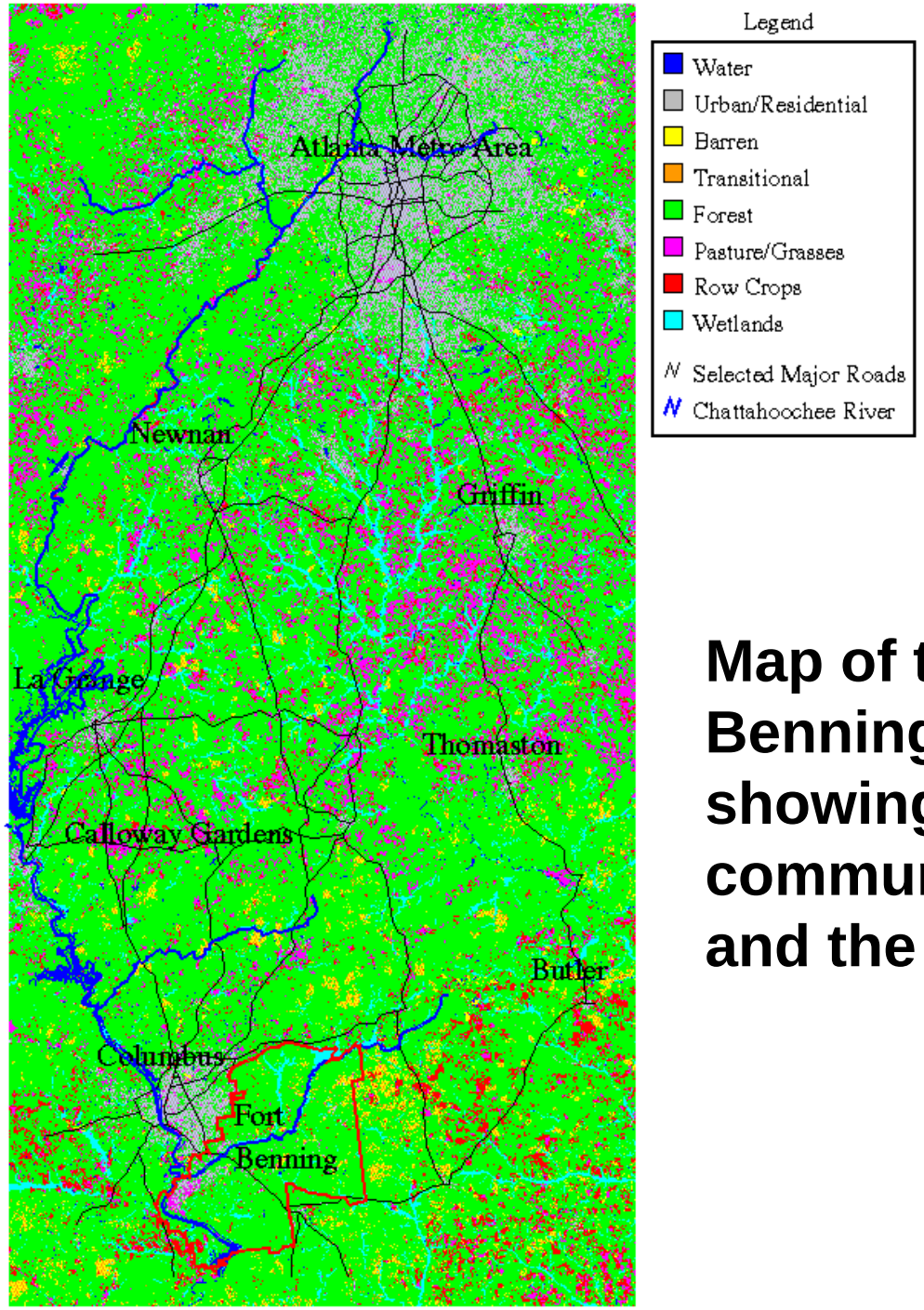
To develop a spatially-explicit simulation model that will enhance the abilities of military planners to understand the implications of

* external land-use change
* resource use, and
* future development policy

on the sustainability of military lands and missions.

Lands adjacent to Fort Benning

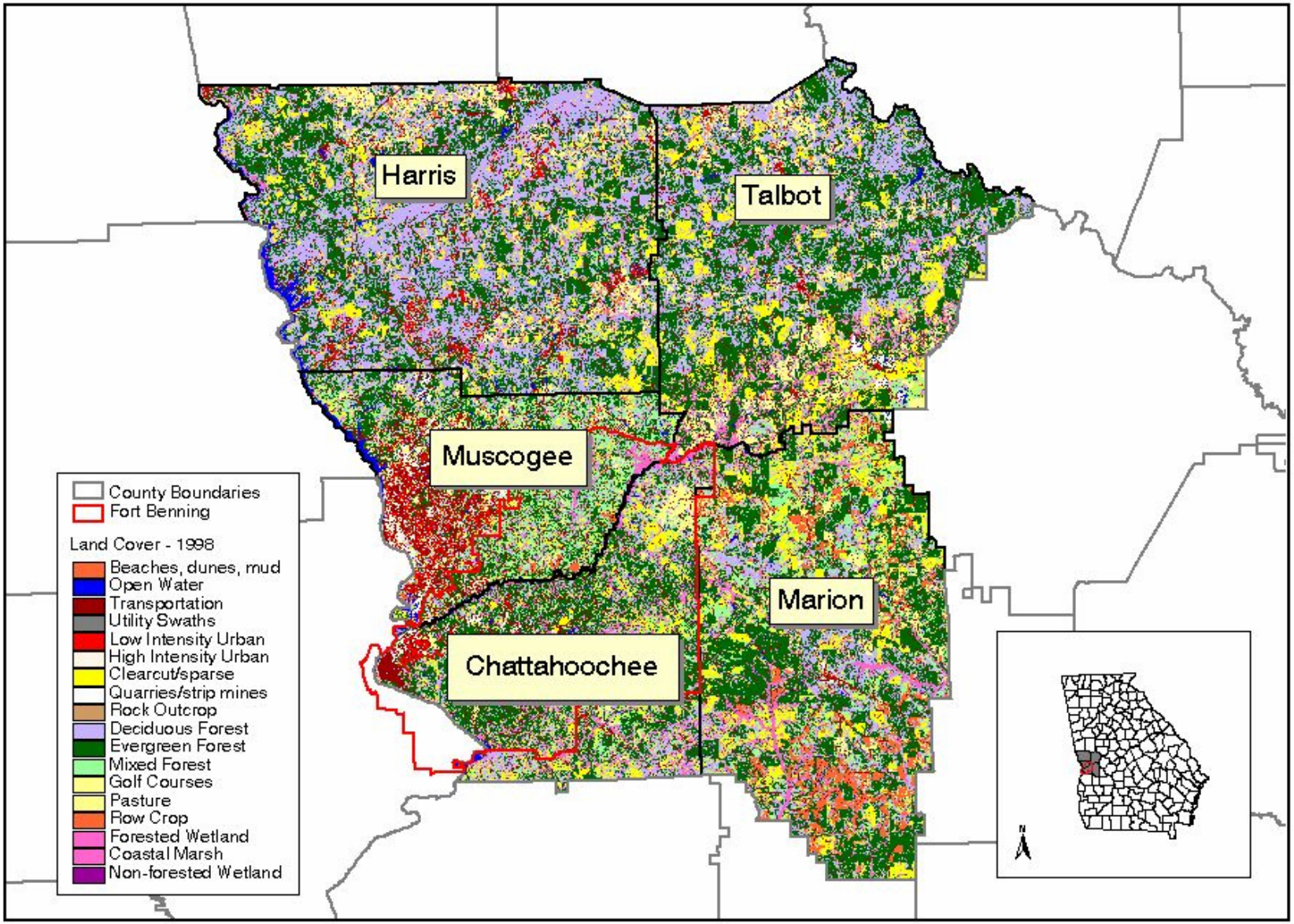

User Interface
* User inputs
- Military use decisions
- Land use decisions
- Ecological concerns
* System inputs
- Time step and duration
- Spatial extent and resolution
GIS Inputs
* Land use (when possible)
* Road networks
* Land cover data
* Soil type
* Rivers and streams
* Noise source locations
* Air pollution sources
* Focal species locations
* Topography
RSim Model
Map Outputs
Changes over Time



Map of the Fort Benning region showing the major communities, roads, and the river.

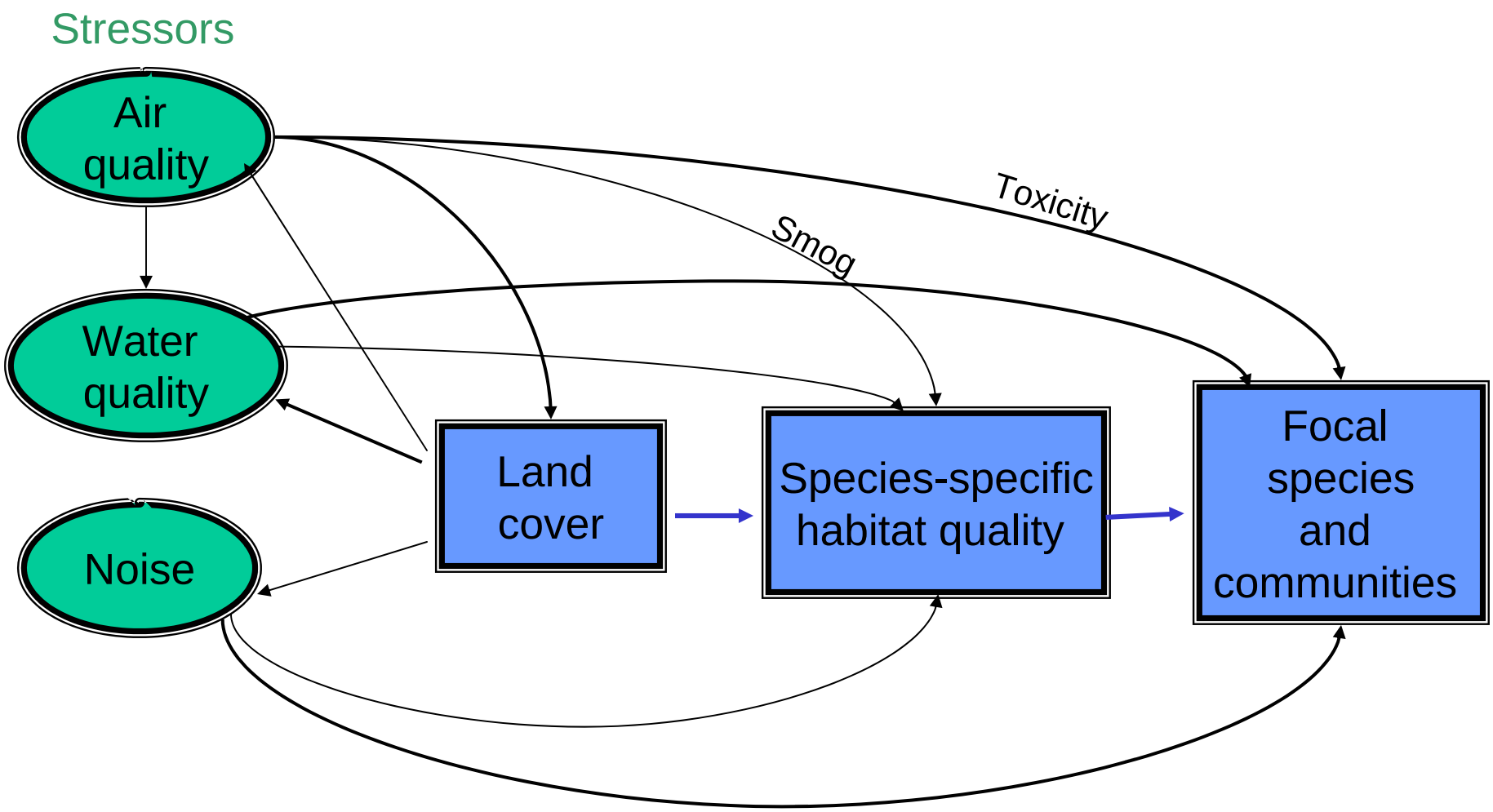
RSim Region

(RSim region encompasses five counties in Georgia.)



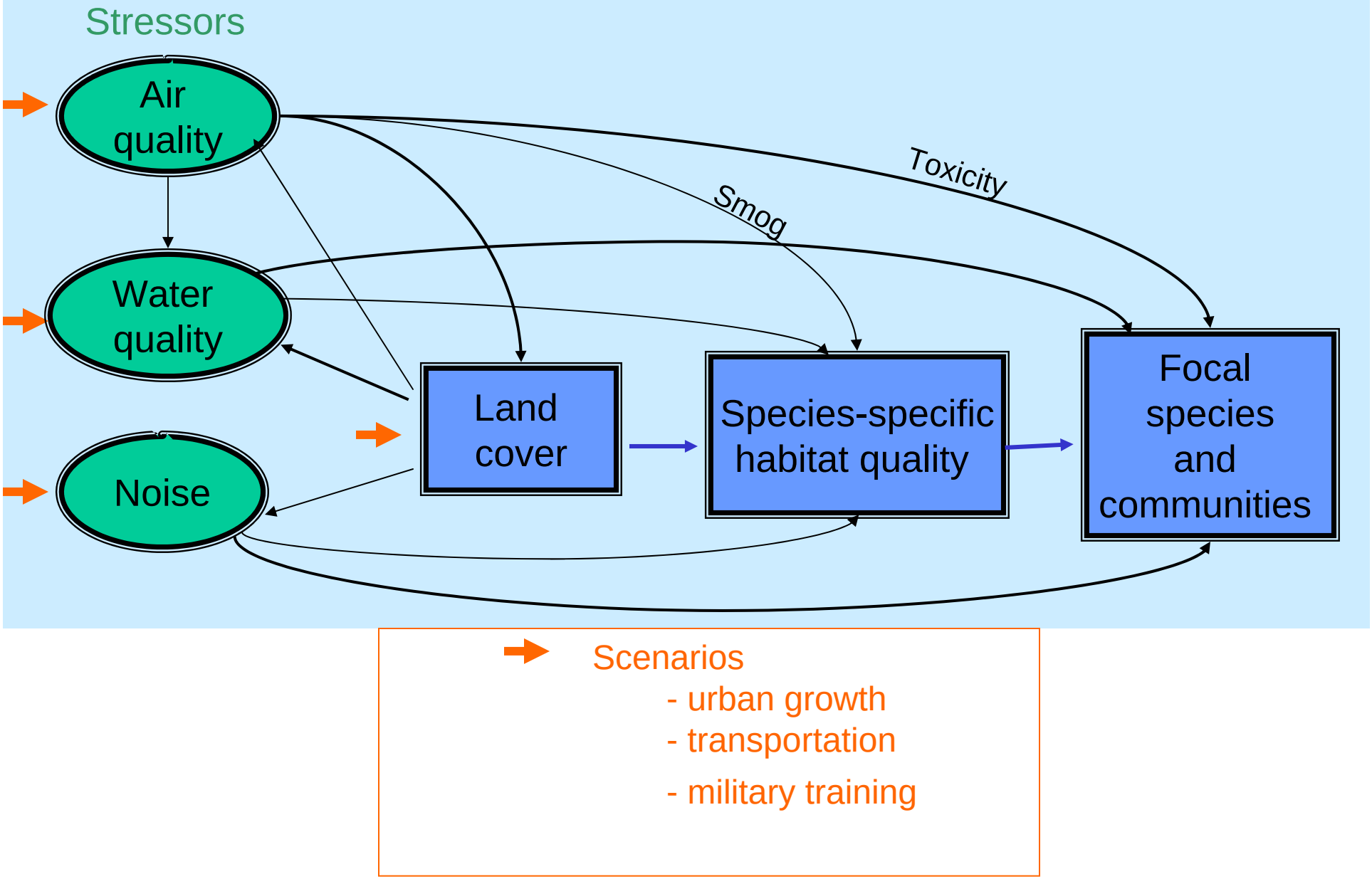
RSim Software Design

- Use Object-Oriented design with Java
- Rule-based approach
- “Evolutionary” process whereby rules may be created or redefined during research phase
- Ultimately, interaction rules between stressors and dependent variables will be fully determined to maintain
  - Reasonability in interactions being implemented
  - Repeatability
  - Flexibility

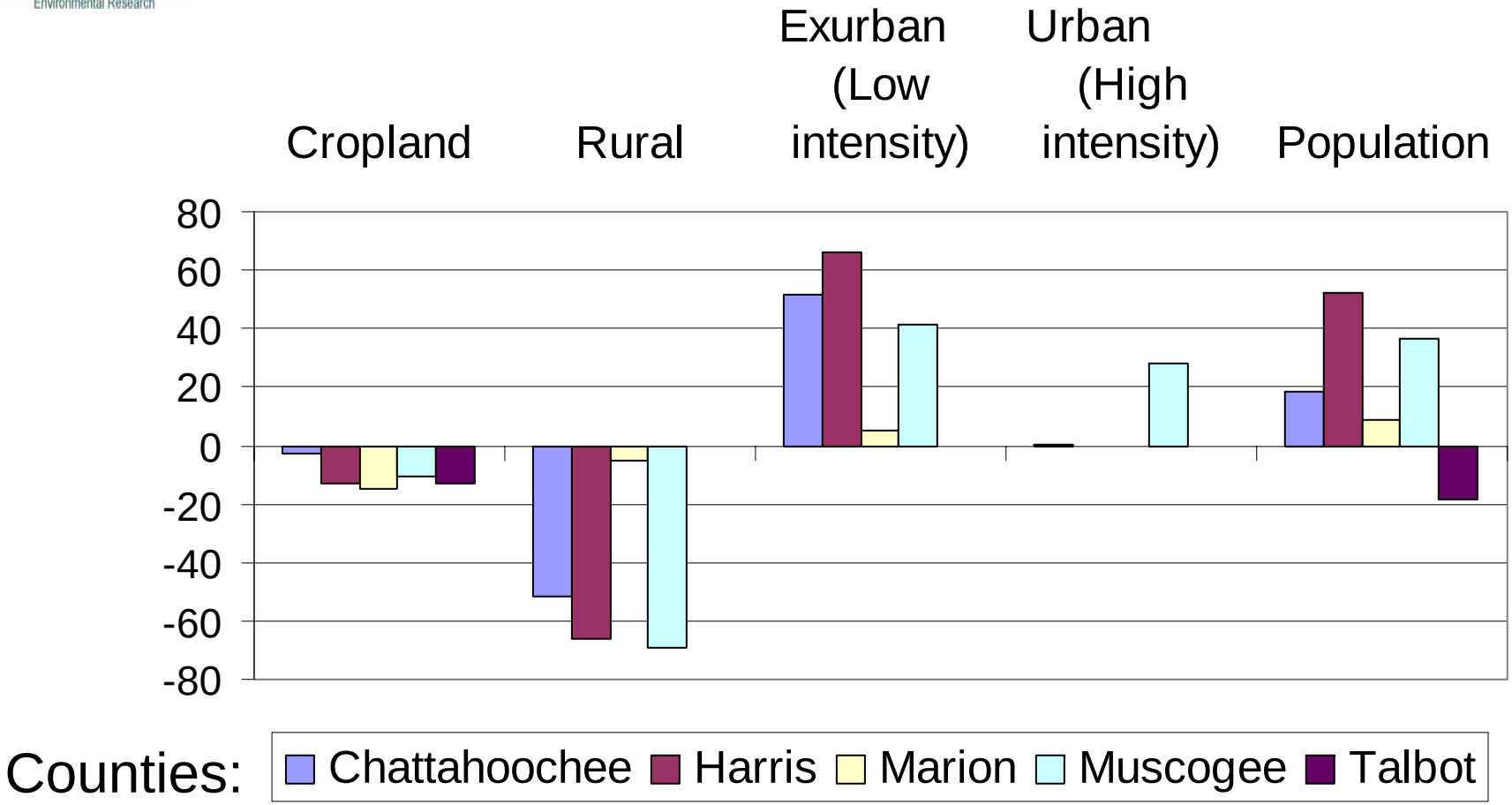


How RSim Models Stressor Effects on Focal Species & Communities

Scenarios Influence RSim



Percent Change: 1950-2000



Sources:

Theobald DM. 2001. The Geographical Review 91:544-564.

Waisanen PJ & Bliss NM. 2002. Global Biogeochemical Cycles.

Brown D. et al. In prep. Ecological Applications.

Categories for Human Cover

- Low intensity
  - Single family residential
  - Urban residential
  - Cemeteries
  - Playing fields
  - Campus-like institutions
  - Schools and parks
- High intensity
  - Central business districts
  - Multifamily dwellings
  - Commercial facilities
  - Industrial facilities
  - High impervious surface areas of institutional facilities

Rules for Urban Growth

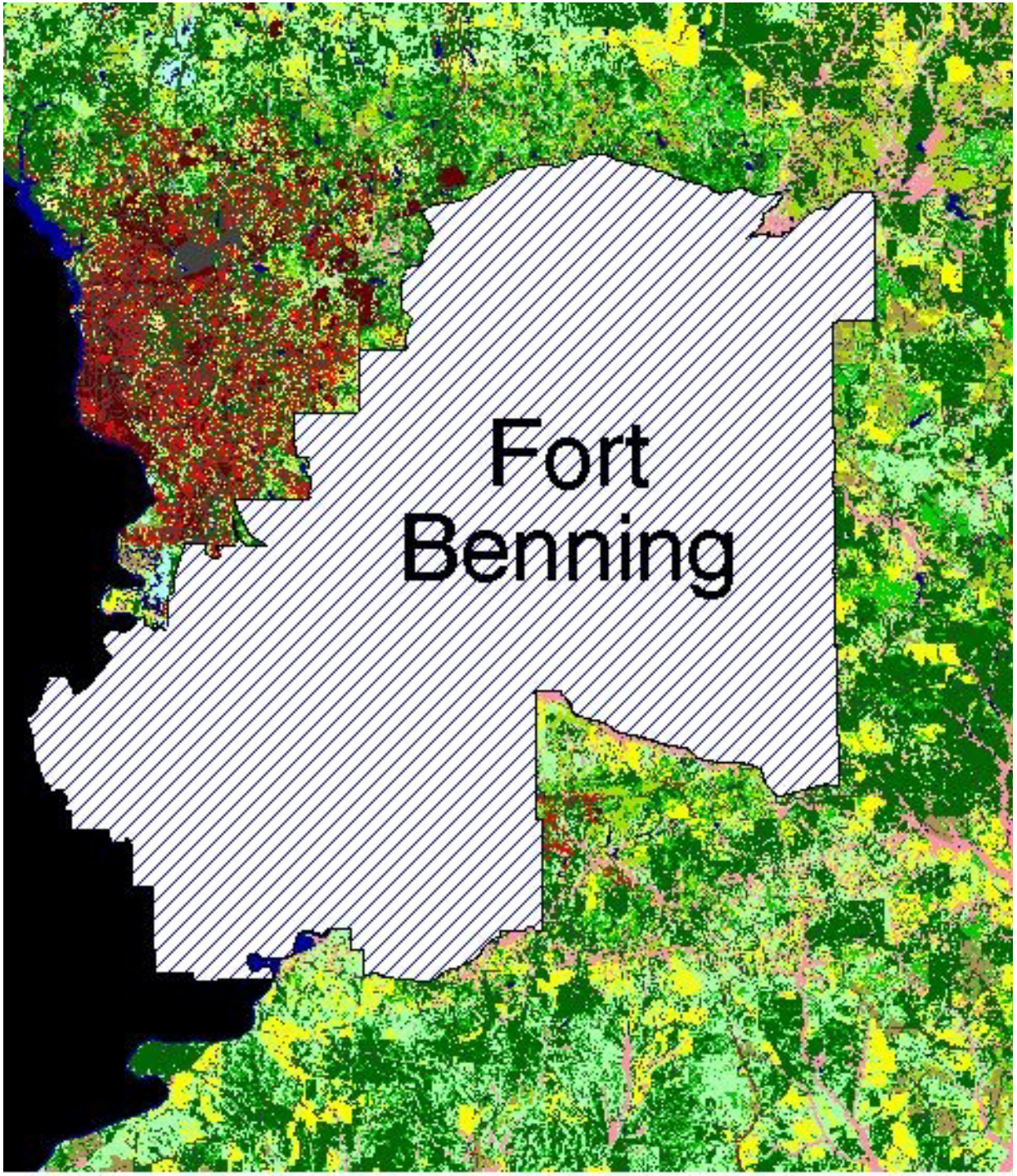
1. Spontaneous Growth
   - Select “seed” pixels at random
   - Urbanize each of those pixels, if they are available for urbanization.
2. New Spreading Center Growth
   - Select a random number of the pixels chosen in Step 1
   - If two neighboring pixels are available for urbanization, urbanize them.
3. Edge Growth (“spreads” centers from those created in step 2 or already urban)
   - Candidate pixels are non-urban pixels with at least three urbanized neighboring pixels.
   - A random number of these pixels are urbanized.

References: Clarke, K.C., Gaydos, L., Hoppen, S. 1996. Environment and Planning B.

Clarke, K. C. and Gaydos, L. 1998. International Journal of Geographical Information Science.

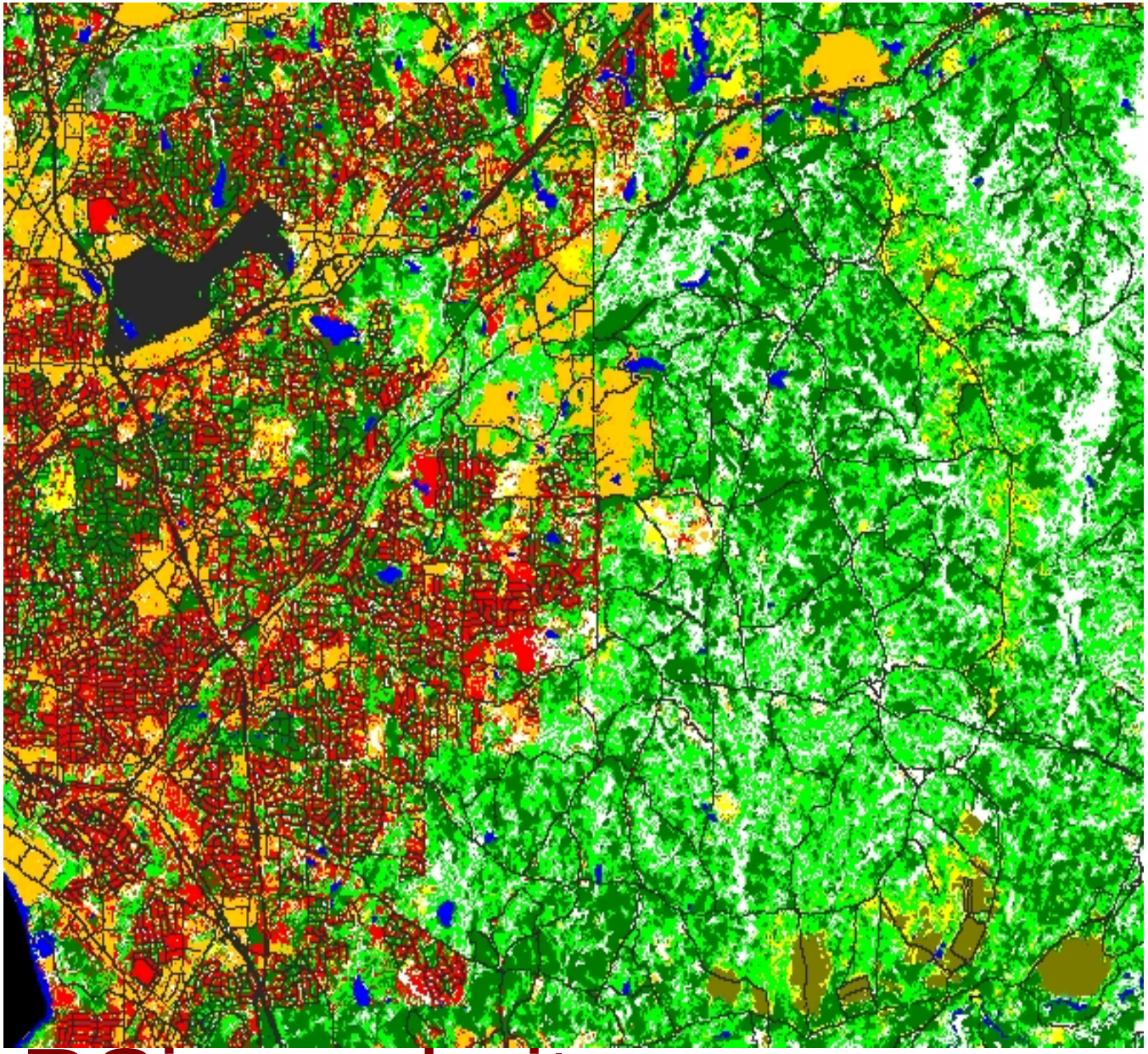
Exclusion Layers:
Where land use cannot change in RSim

1. Transportation
2. Open water
3. Military lands
4. Parks and protected private lands



ornl
OAK RIDGE NATIONAL LABORATORY

- Beaches, dunes, mud
- Open water
- Transportation
- Utility swaths
- Low intensity urban
- High Intensity urban
- Clearcut/sparse
- Quarries/strip mines
- Deciduous forest
- Mixed forest
- Evergreen forest
- Golf courses
- Pasture
- Row crops
- Forested wetlands



Urban Growth Scenario

- Beaches, dunes, mud
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- Utility swaths
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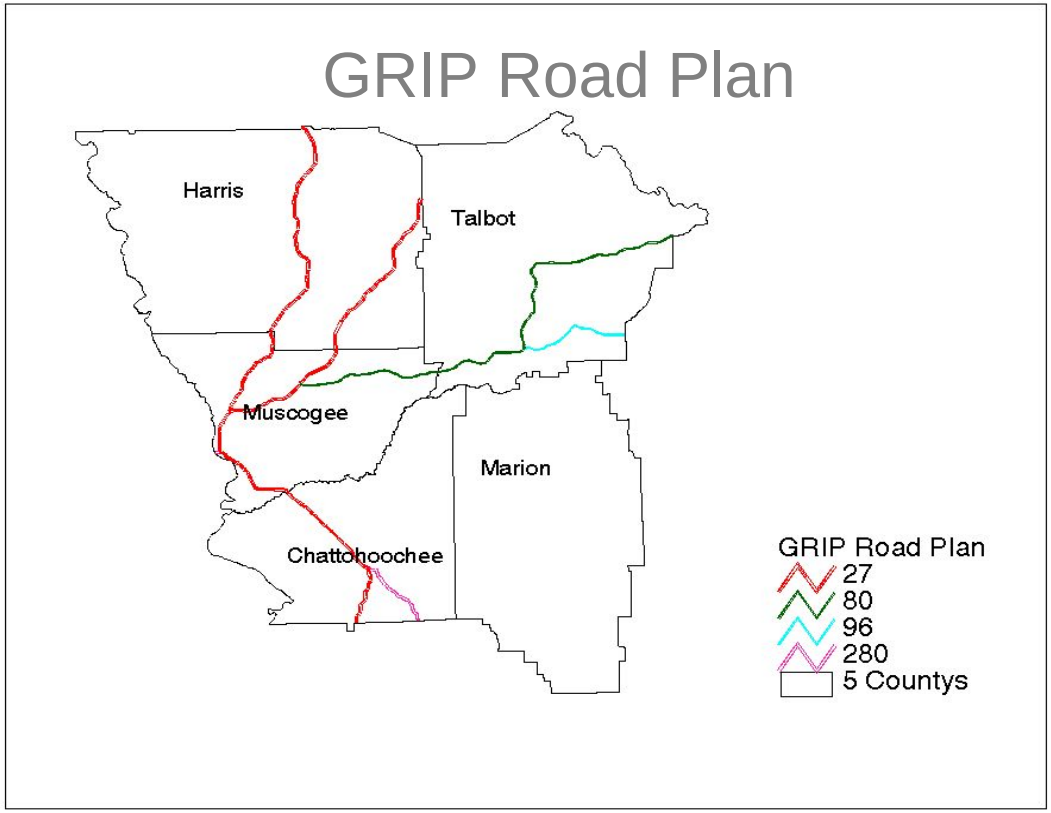
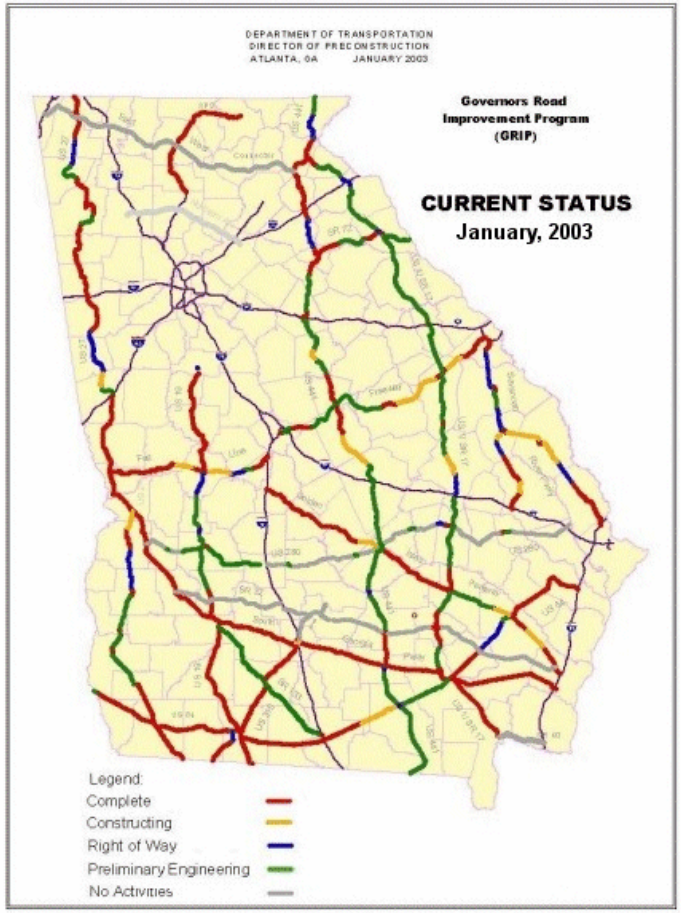
RSim website:

www.esd.ornl.gov/programs/SERDP/RSim/index.html

Proposed Road Plans for RSim Region

- Governor's Road Improvement Program (GRIP):
  - to widen two-lane roads
  - to attract economic development by improving the state's highway network





Rules for Growth along Roads

- Determine if a major road is within a predefined distance from each new urban pixel.
- If so, seek out other potential pixels for urbanization.
  - If possible, move along a road a predefined travel limit distance.
    - Such travel can be further along larger four lane roads than smaller two-lane roads.
    - Constitutes a successful road trip
    - Three neighbors are considered for urbanization:
      - » Immediate neighbors of the final road pixel visited are tested for potential urbanization.
      - » If found, pixel is changed to an urban type, and its immediate neighbors are also tested.
  - Result is a new urban center that may result in spreading growth

Projected Growth along Roads

- Beaches, dunes, mud
- Open water
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- Utility swaths
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- High Intensity urban
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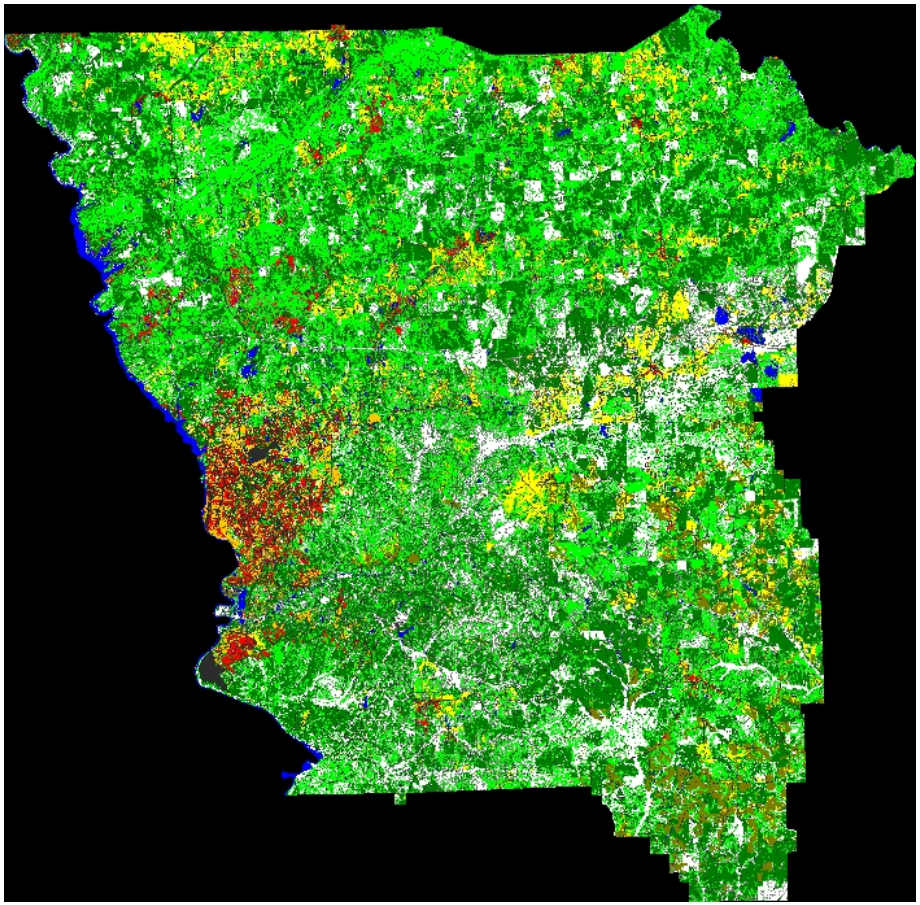
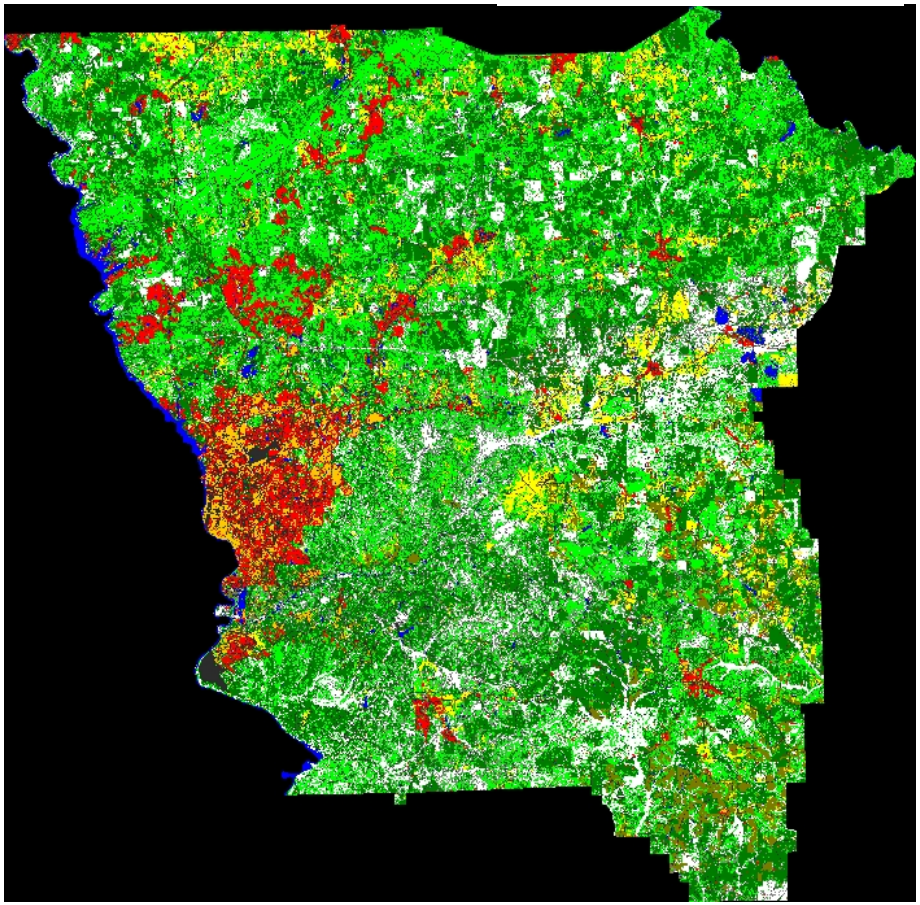
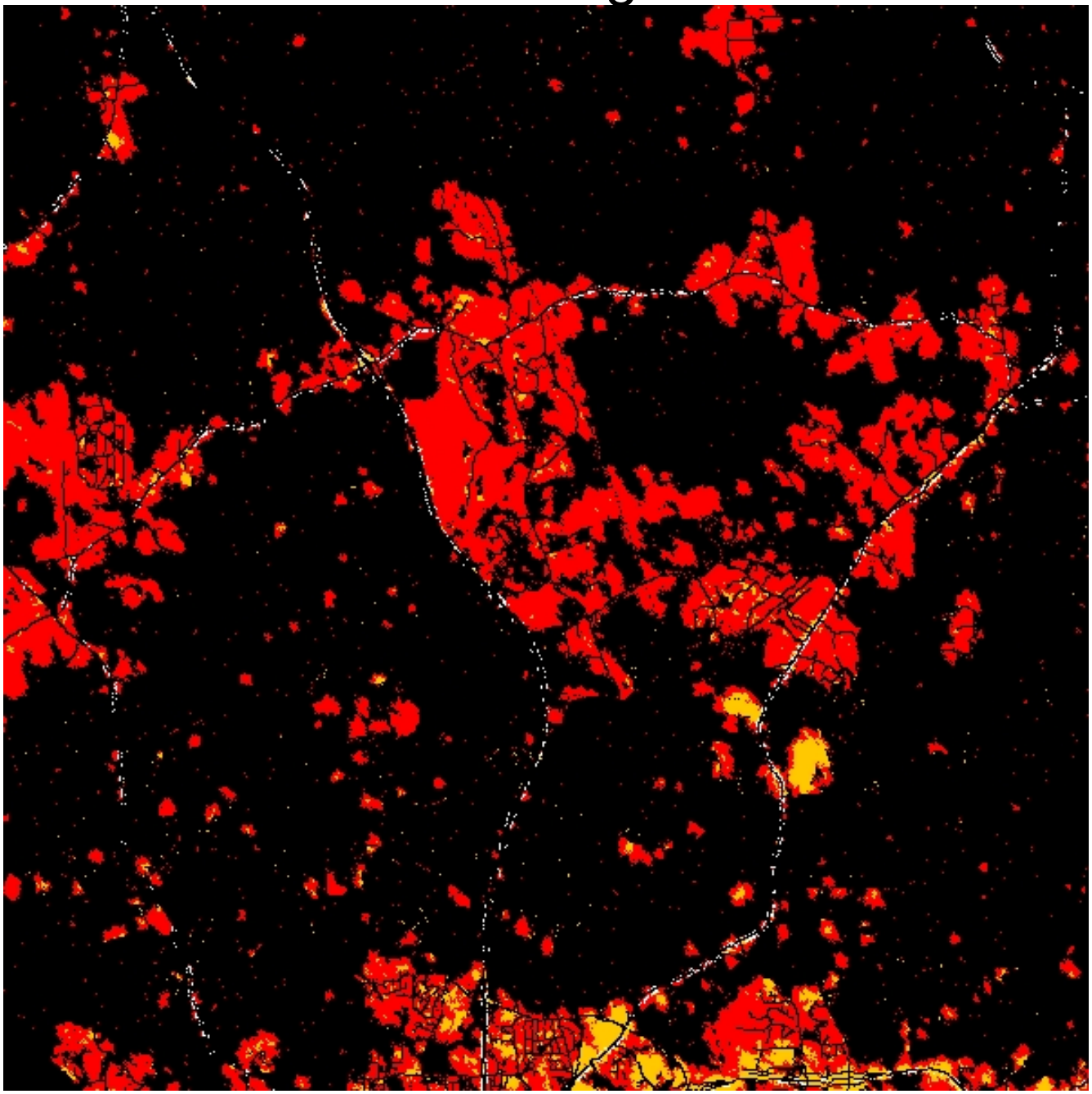
1998



Projected



Changes to Columbus area:



= high intensity urban growth

= low intensity induced growth

= road induced growth

Scenario Manager

- Offered in two modes
  - Pop-up menu with slide bars and options to select curve forms
  - Bundled choices
- Scenario components
  - Modeled changes
    - Population (user specifying % increase, date to increase, curve form, spatial distribution)
    - Land-cover or use changes (e.g., decline in agriculture)
  - Maps of new conditions
    - Roads
    - Military training sites (e.g., proposed multipurpose range complex, Company Team Defense Project)

Output Manager

- Maps
  - Land cover changes
  - Projected land cover
  - Changes in habitat conditions
  - Risk maps
  - Noncompliance maps
- Changes over time
  - Noise conditions
  - Air quality
  - Water quality
  - Populations & communities

Model Component: Air Quality

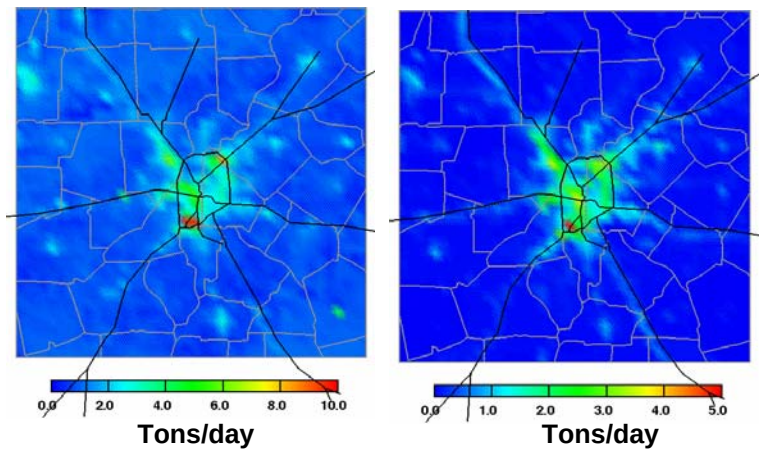
Community Constraints/Aspirations
e.g. mission requirements, mobility, land use, economic development, etc...

Atmospheric Stressors / Emissions Sources

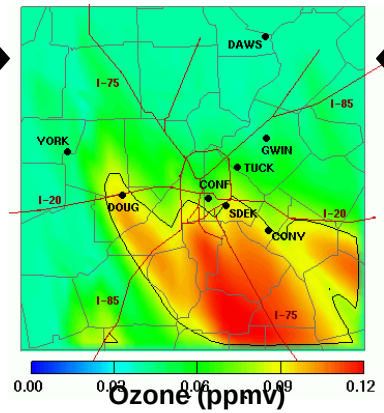
- Point
- Non-road mobile
- Area
- Mobile
- Biogenic

Atmospheric Constraints
e.g. climate, transport mechanisms, carrying capacity, chemical composition, air quality standards, etc...

Emissions

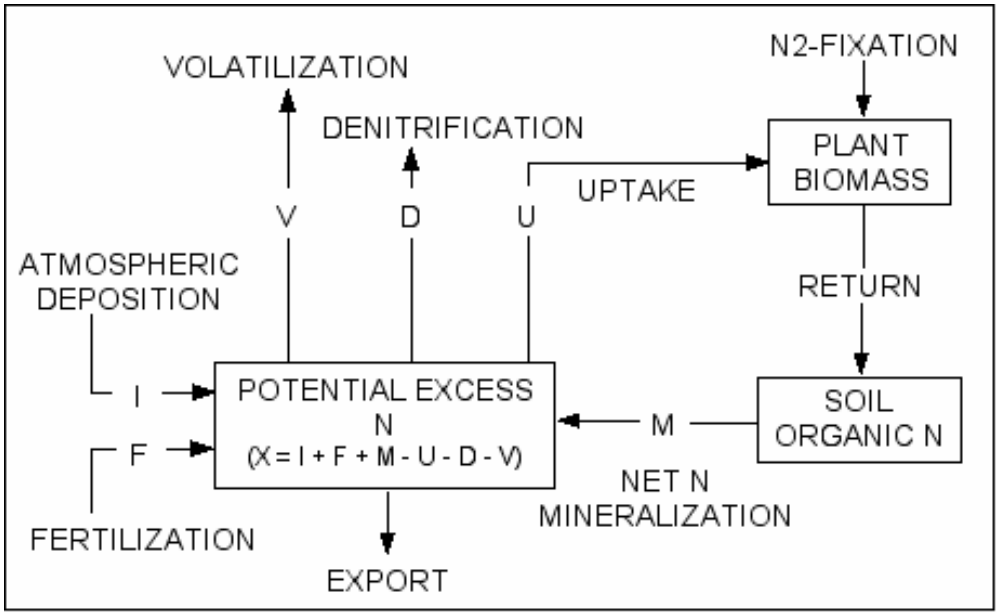


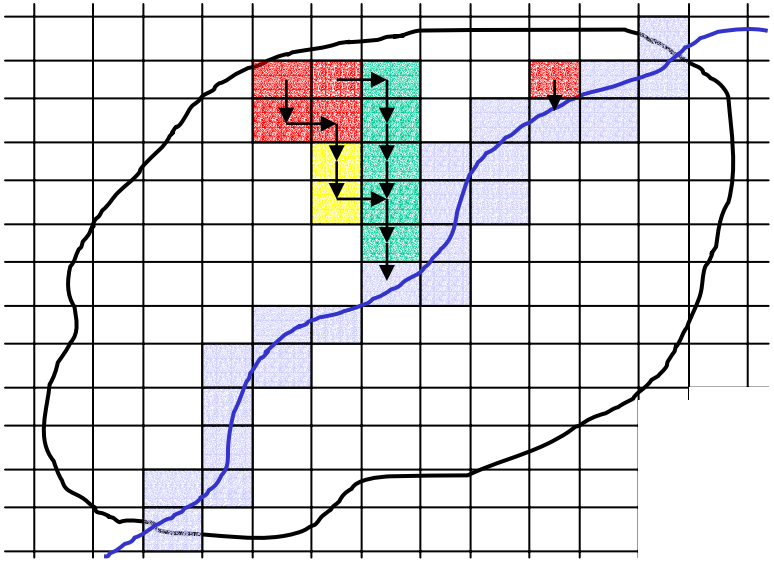
Ozone Pollution

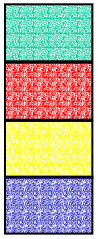


Model Component: Water Quality and Nitrogen Flux

- The Neuse River model is being adapted to region
- Simple hydrological input is being incorporated







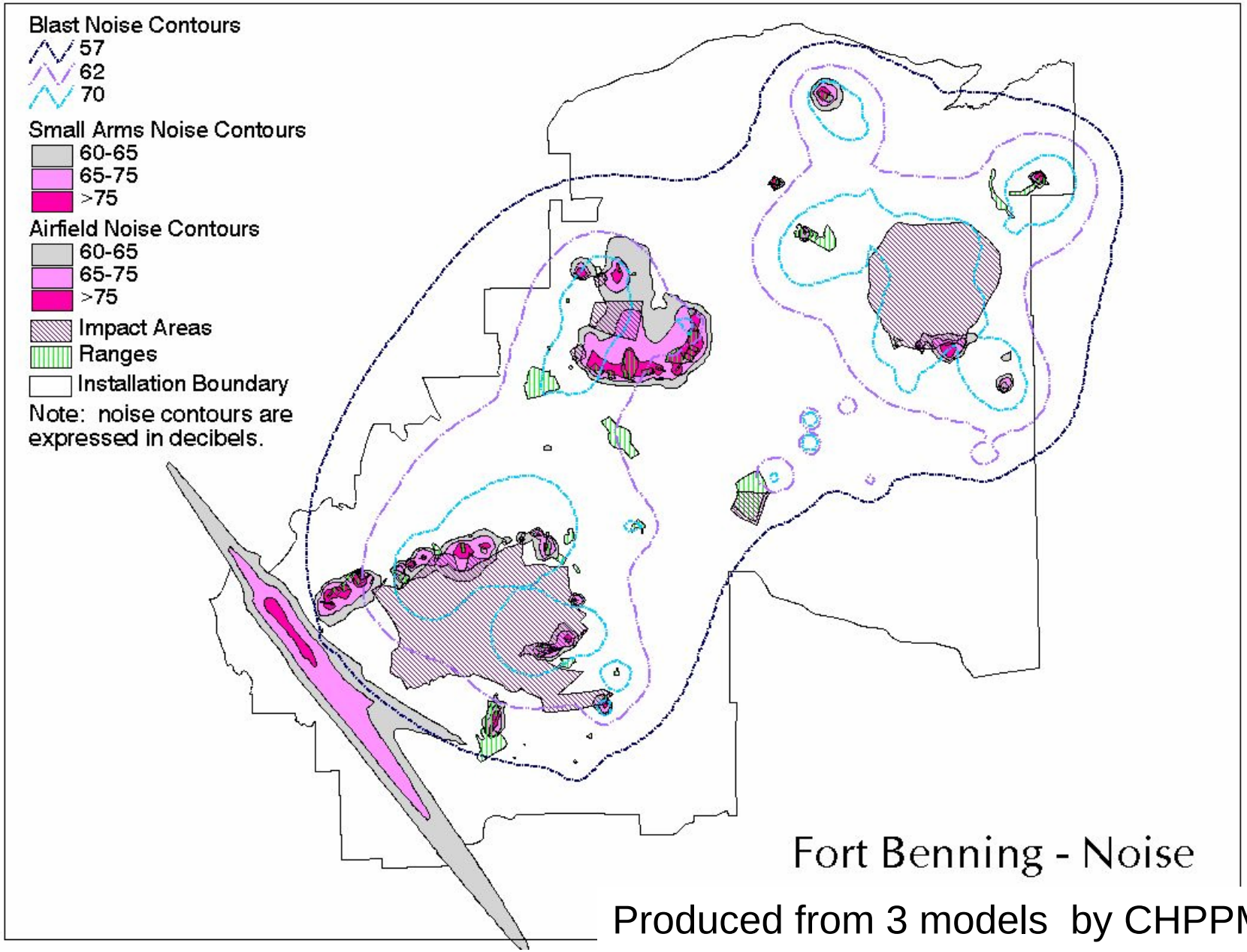
Potential Sink for Excess N
Potential Source of Excess N
Neither Source nor Sink
Stream

Reference:

Garten & Ashwood. 2000. ORNL TM 2000/282.

Garten & Ashwood. 2003. Water, Air, Soil Pollution.

Model Component: Noise



Produced from 3 models by CHPPM

Model Component: Focal Species and Communities

Data on species occurrence and potential for occurrence:

*Fort Benning
*The Nature Conservancy
*Soil data

Data on habitat:

*Fort Benning: ECMI and LCTA
*EPA's Southeastern Ecological Framework (SEF)
* Longleaf Pine Alliance

Models of species presence and habitat availability, e.g.

*Gap crossing models (Pearson 1994, Pearson et al. 1996)
*RCW regional models (King et al. in press)

Scenario constraints

Constraints from other factors:

*Noise
*Water or nutrients
*Air

Species and habitat effects

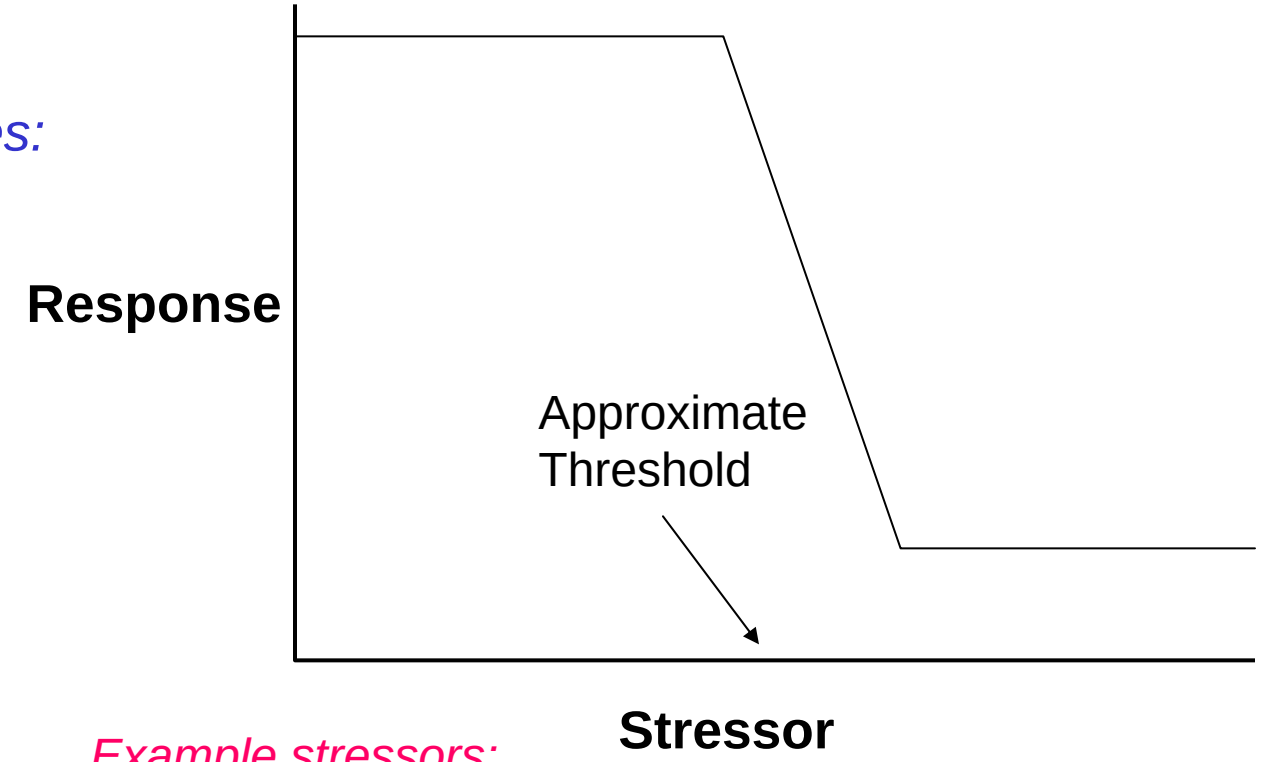
Ecological Risk Assessment Filter

- Improve Military Ecological Risk Assessment Framework (MERAF) methodology for integrating exposures and effects from military and civilian activities
- Develop distributions of critical effects thresholds for risks
- Build risk results into RSim

Ecological Effects Thresholds for Risk Assessment

Example responses:

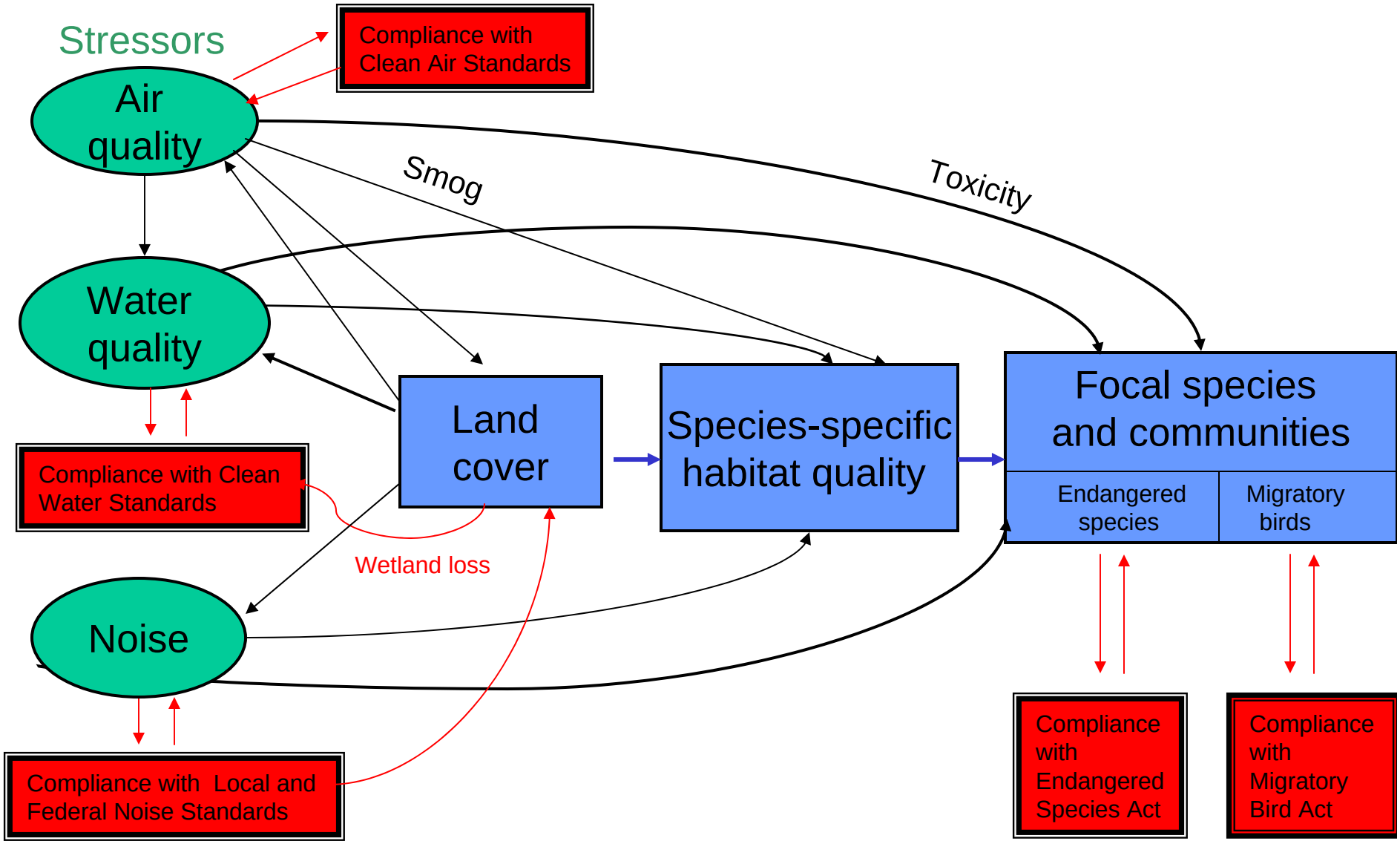
- Tree production
- Amphibian abundance
- Woodpecker reproduction
- Tortoise reproduction



Example stressors:

- Increasing concentration of ozone in air
- Increasing concentration of nitrate in stream
- Increasing level of noise
- Decreasing habitat patch size
- Decreasing distance from sound source

Interactions of RSim with Environmental Laws and Regulations

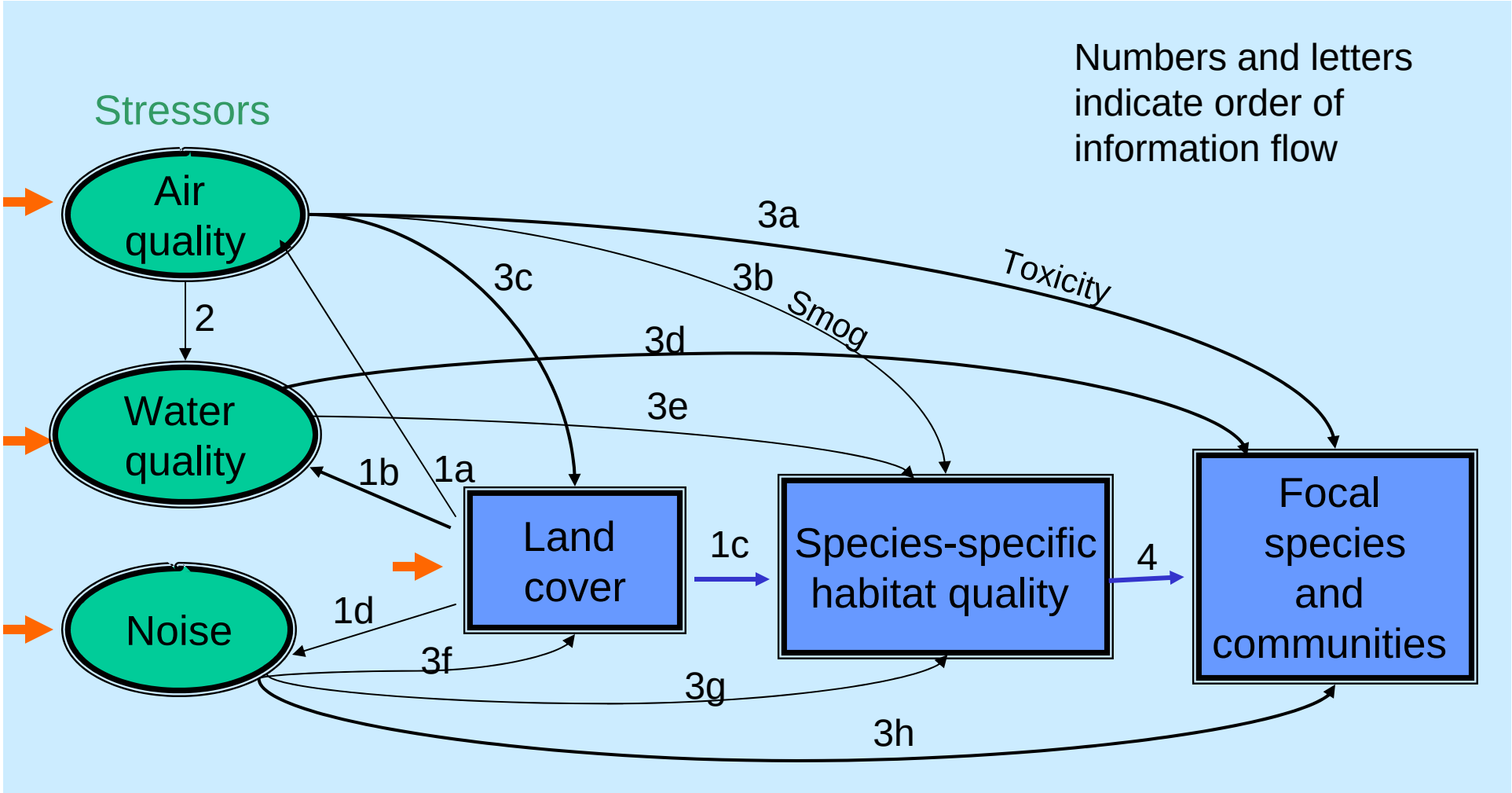


RSim can be a scoping tool for the National Environmental Policy Act (NEPA)

External Review of RSim

- Performed by Dr. Richard Flamm
  - Florida Marine Research Institute
  - Designed LUCAS (Land Use Change Analysis System)
  - Developed model user interface based on stakeholder perspective
- Focused on integration
  - Order of events
  - Scales of environmental effects
  - Feedback effects

Order of operations



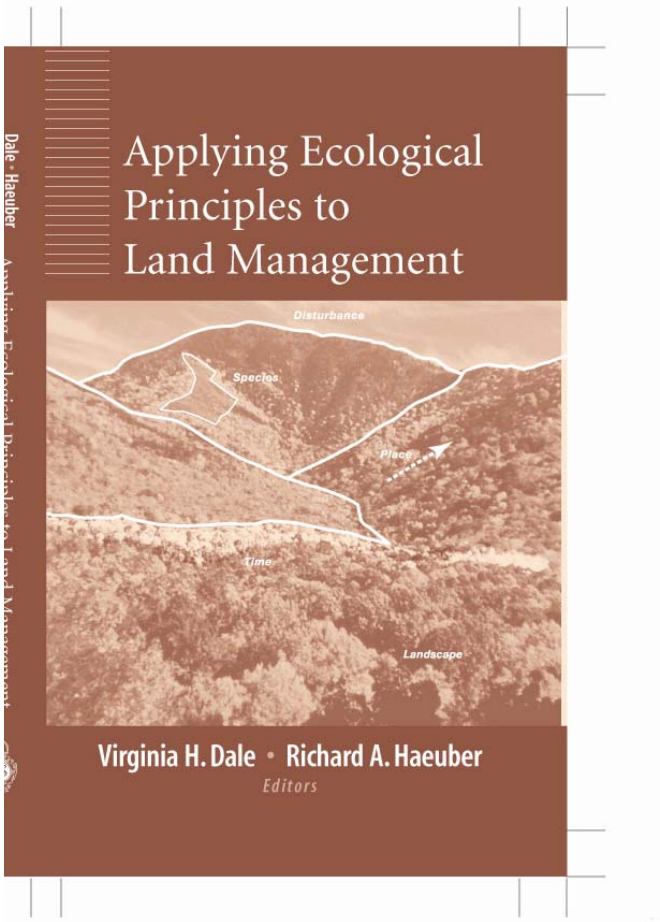
Innovative Science

- Scales: an approach that integrates processes that operate on different temporal and spatial scales
- Feedbacks: Incorporating feedbacks between different aspects of the environment that operate at different scales
- Optimization: Consider several criteria at the same time dealing with air, water, noise and species.
- Advances within each module (air, water, noise and species).
- A regional perspective

Transition Plan

- Formal review of effort
- Interpret results in a meaningful way to resource managers
- Active use of RSim by resource managers
- Web-based integrated model
  - Provides RSim in an accessible form
  - Can be used in gaming mode

Deliverables



- Software for spatially-explicit model that simulates changes in ecological conditions under different land-use and management strategies,
- Application of the software to the Fort Benning region
- Peer reviewed publications
- Key components of the approach needed to identify, characterize and project impacts of regional land use change

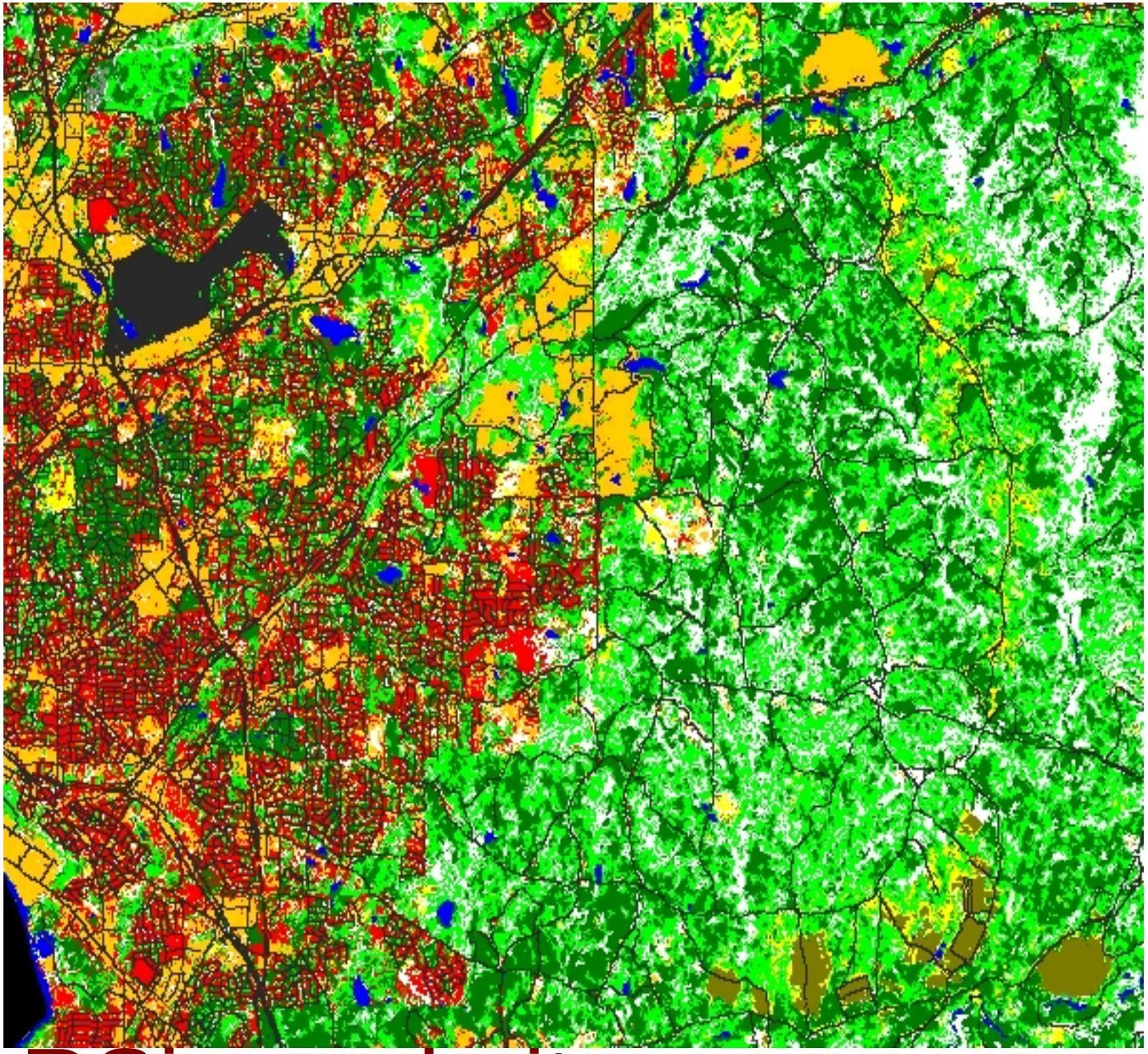
Products to Date

- Publications
  - Dale,V.H., S. Archer, M. Chang, & D. Ojima. Submitted. Understanding of ecological processes facilitates land management. *Ecological Applications.*
  - Dale, V.H., Druckenbrod, D.,Baskaran, L., Aldridge, M., l Berry, M., Garten, C., Olsen, L., Efroymson, R., and Washington-Allen, R. In internal review. Vehicle impacts on the environment at different spatial scales: Observations in west central Georgia. *Journal of Terramechanics.*
- Presentations
  - Ecological Society of America Symposium on "Land Use Change," August 2002 In Tucson, AR
  - Pardee Symposium at the Geological Society of America, October 27, 2002 in Denver, CO
  - Research coordination meeting for studies in the Fort Benning region, Columbus, GA, October 30, 2002
  - University of Tennessee, November 2002, Knoxville, TN
  - University of Washington, March 2003, Seattle, WA
  - University of Michigan, March 2003, Ann Arbor, MI
  - American Society of Agronomy Symposium on "Military Land Use and Management," November 2003, Denver. CO

Program In Kind Support

Task	DoD Noise models*	Fall Line Air Quality Study (GA)	Neuse River Study (EPA and DOE)	Fort Benning	SEMP	SERDP (Odman)	SERDP 1054	SERDP 758	TNC	Forest Service	SE Frame work (EPA)	LMS
Development & testing of simulation model for Benning region				Data	Data					Development of LUCAS	Data	
Water quality/N dynamics interface			Model	Water quality data	Data						Data	
Air quality interface		Data for region				Regional impacts					Data	
Noise interface	Models applied to Benning			Noise data							Data	
Species & critical ecosystems interface				LCTA data	ECMI data			Ecological models	Data on rare species & habitats		Data	
Changes in land use & cover for region					Land changes at Benning						Data	
Simulation model exercises for decision support												
Integrating multiple contraints									Ecoregional approach to integration			
Ecological risk assessment support							Risk assessment approach					
Transition: web based interface												Context

*Office of Economic Adjustment, HQ Naval Facilities Engineering Command, and Air Force Research Laboratories



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