Using State-and-Transition Simulation Models to Guide Sustainable Management of Ecosystems: Three Case Studies from across the US

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Outline

- Overview of State-and-Transition Modeling
- Climate Change

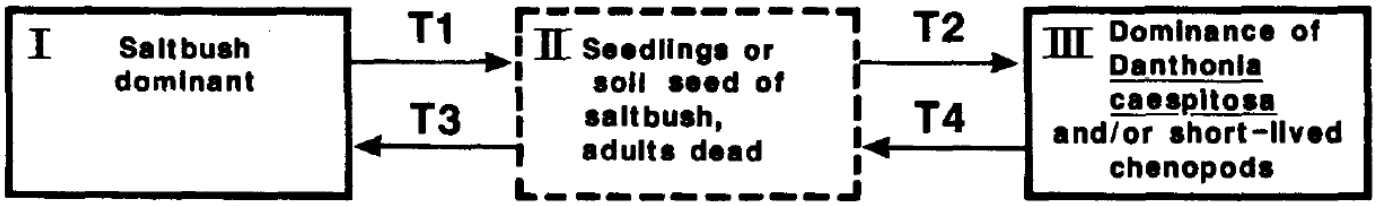
Outline

- Overview of State-and-Transition Modeling
- Climate Change
- Whitebark Pine
  - Combining STSMs and Species Distribution Models
- Longleaf Pine
  - Modeling effects of climate change, urbanization, & fire
- Rangeland Condition and Greater Sage-Grouse
  - Integrate STSMs, Species Distribution Models, and a Dynamic Global Vegetation Model

Case Studies

State-and-Transition Models

- Conceptual Models
  - Represent groups of vegetation communities and shifts between them (Westoby et al. 1989)



Source: Example from Westoby et al. (1989)

State-and-Transition Models

States

- Suites of veg. communities
  - Cover type, structural stage, age
- Based on objectives
- Limited by data

State-and-Transition Models

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- Suites of veg. communities
  - Cover type, structural stage, age
- Based on objectives
- Limited by data

Transitions

- Key processes influencing vegetation
- Natural (e.g., succession, fire, drought, dispersal)
- Anthropogenic (e.g., grazing, planting, urbanization)

State-and-Transition Simulation Models

- State-and-Transition Models
  - Conceptual models representing groups of vegetation communities and shifts between them (Westoby et al. 1989)

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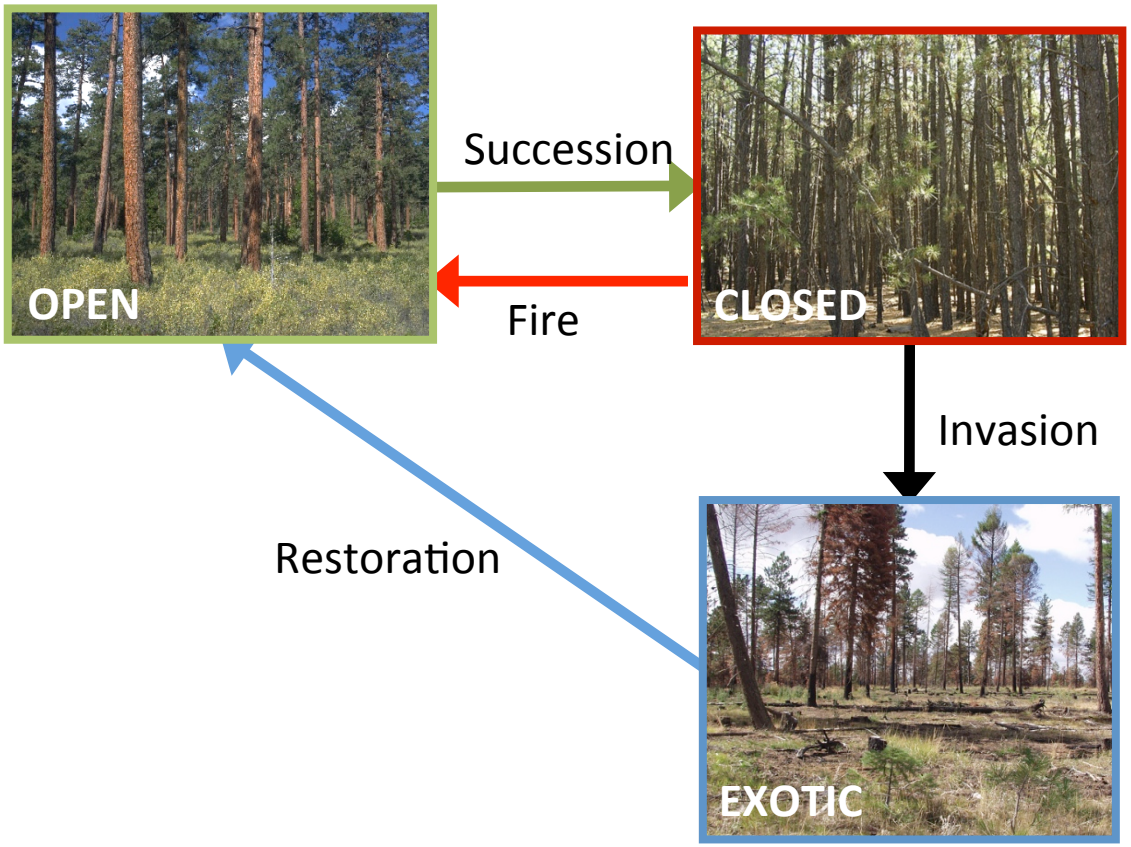
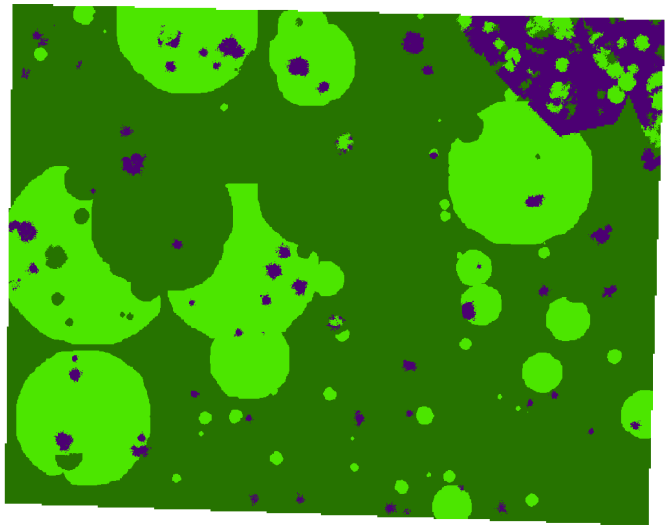
- Simulations
  - Computer-based prototype of real world
  - Complexity: thresholds, secondary effects, emergent patterns
  - Virtual Laboratory: "What if" Scenarios

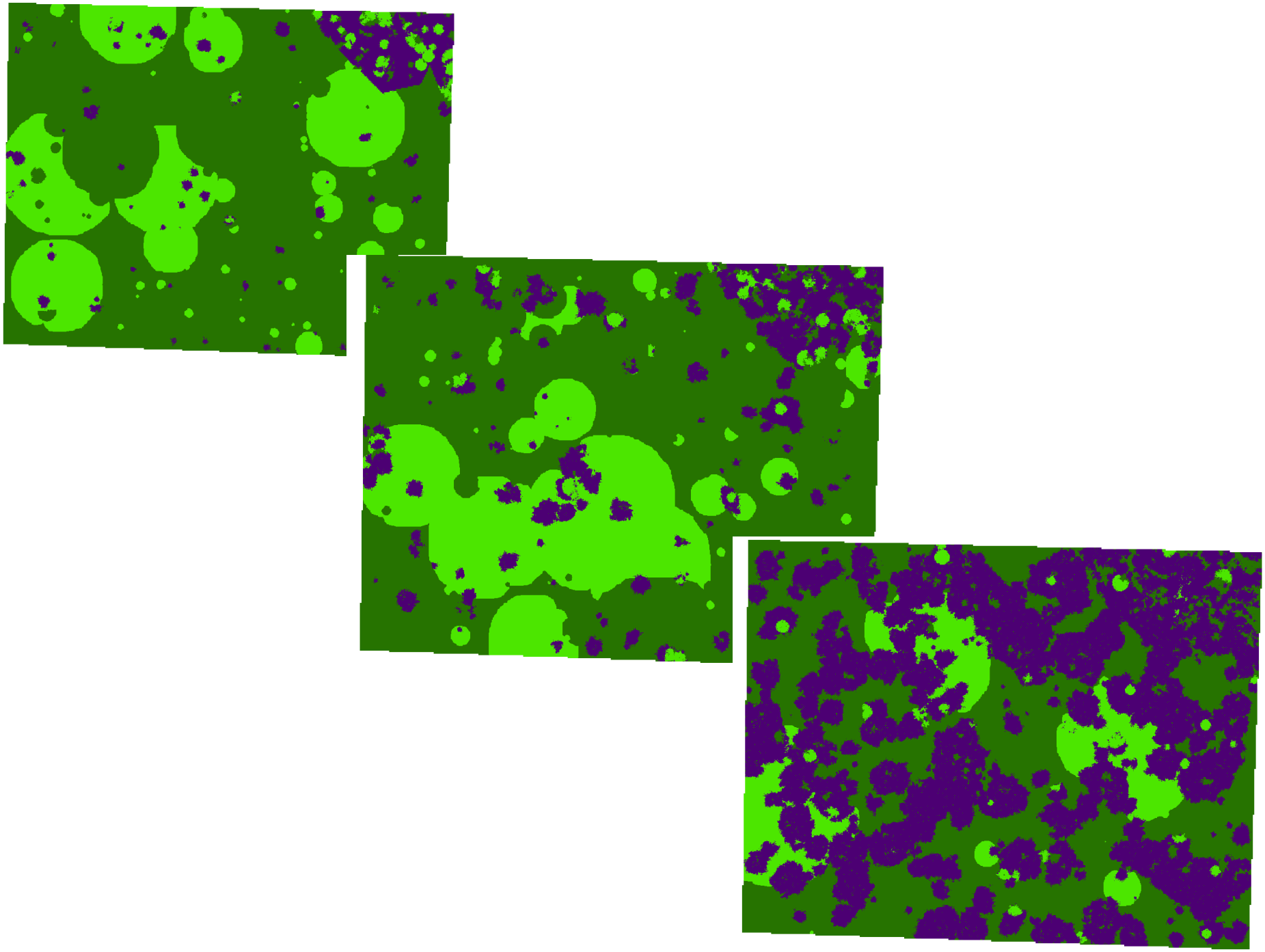
State-and-Transition Simulation Models

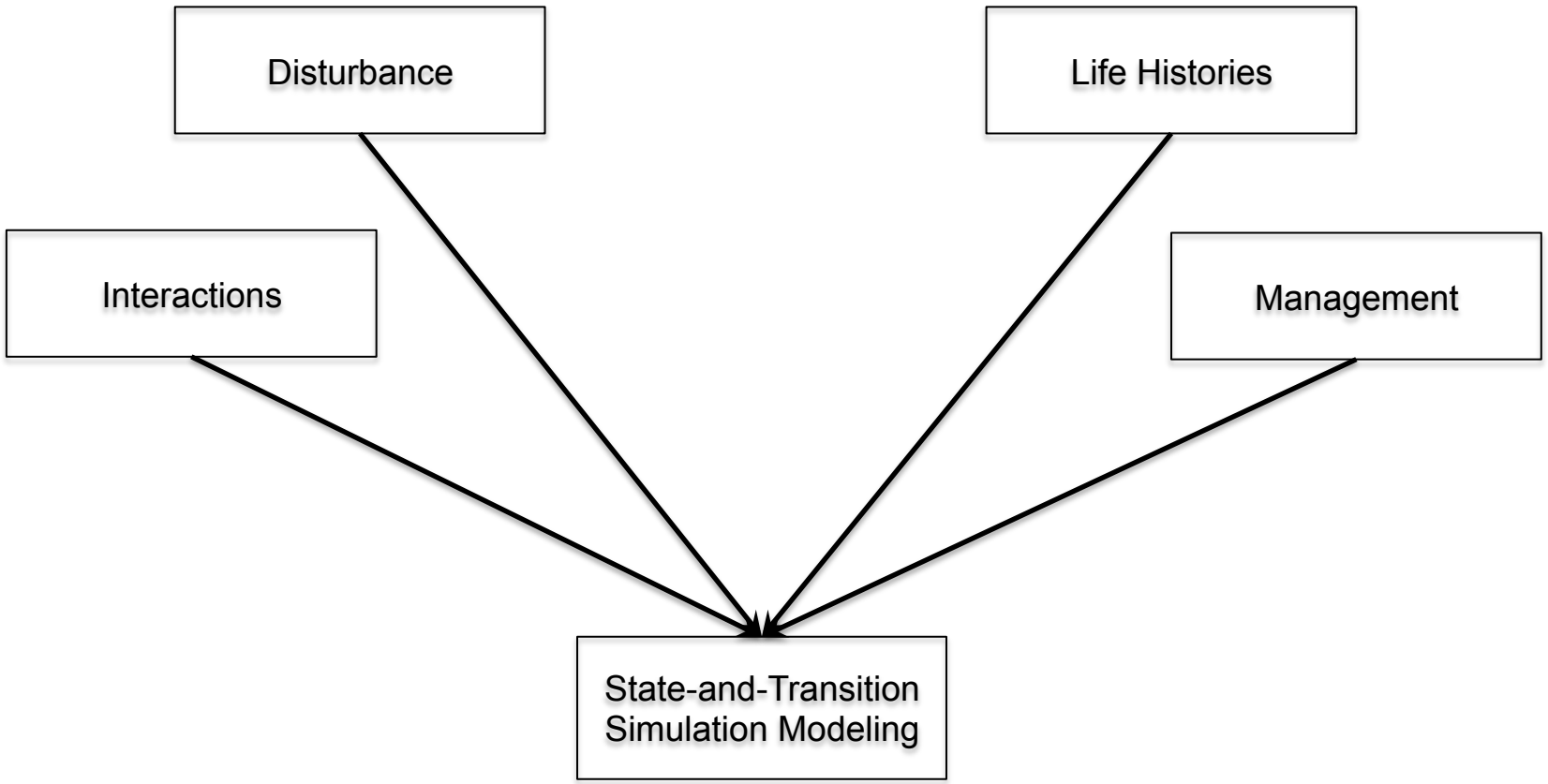
- State-and-Transition Models
  - Conceptual models representing groups of vegetation communities and shifts between them (Westoby et al. 1989)
- Simulations
  - Computer-based prototype of real world
  - Complexity: thresholds, secondary effects, emergent patterns
  - Virtual Laboratory: "What if" Scenarios
- STSMs: State-and-Transition Simulation Models
  - Temporally dynamic, spatially explicit
  - Biotic interactions, disturbance, and management scenarios

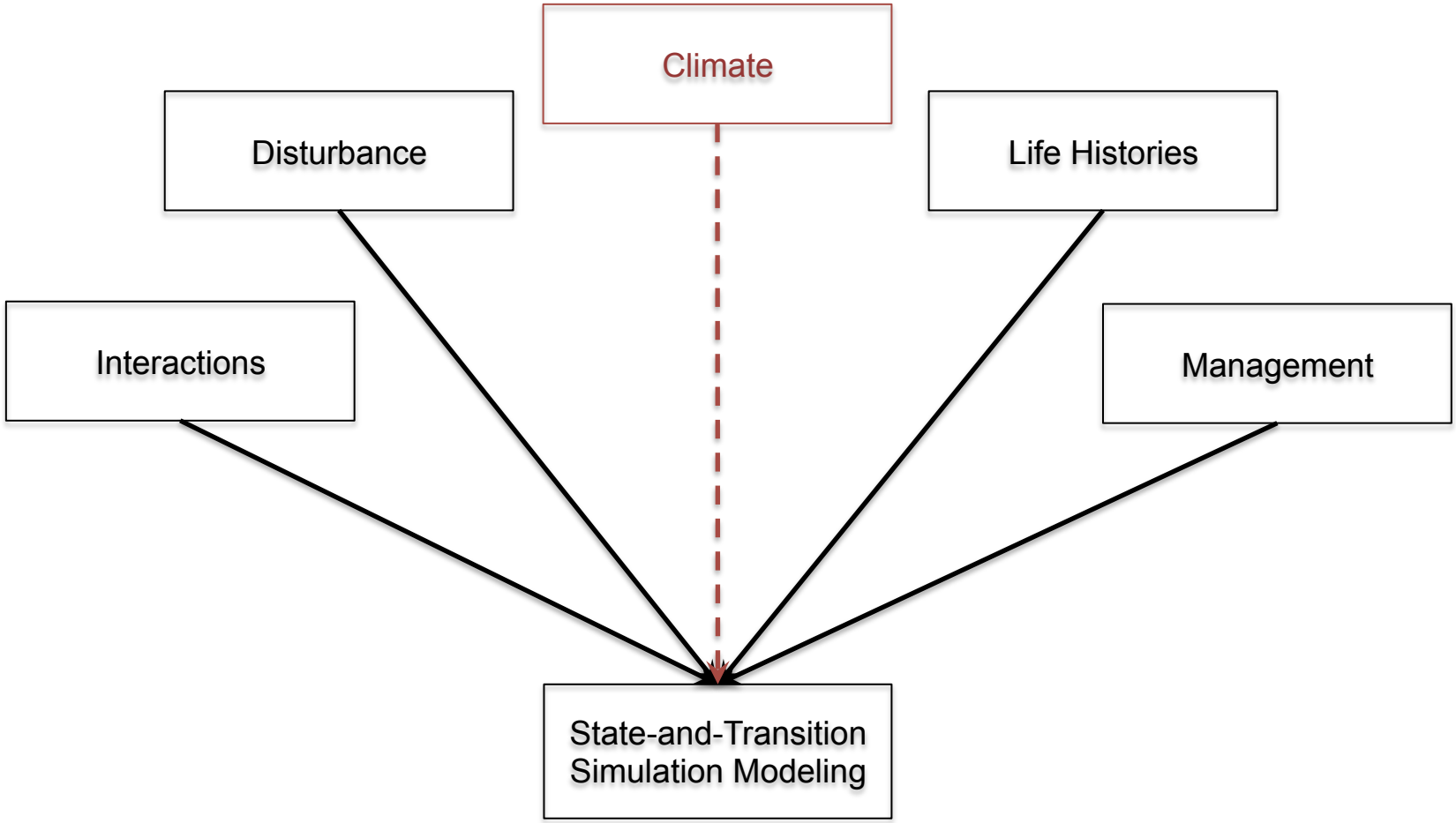
Example Model








Disturbance
Life Histories
Interactions
Management
State-and-Transition
Simulation Modeling


Climate
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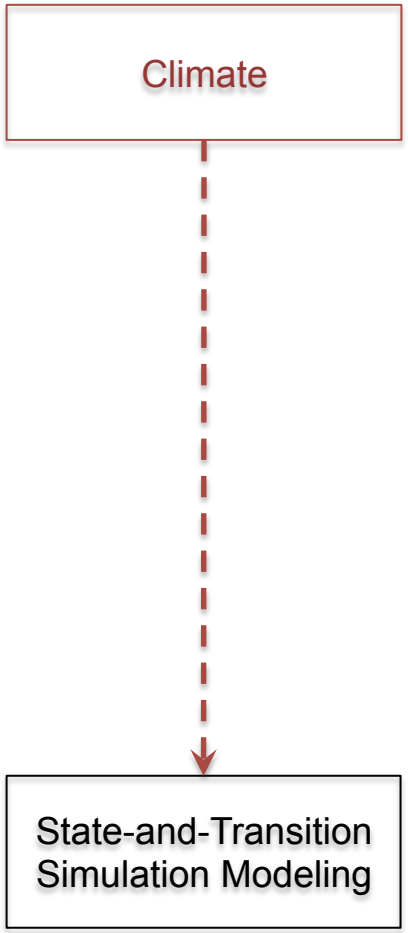
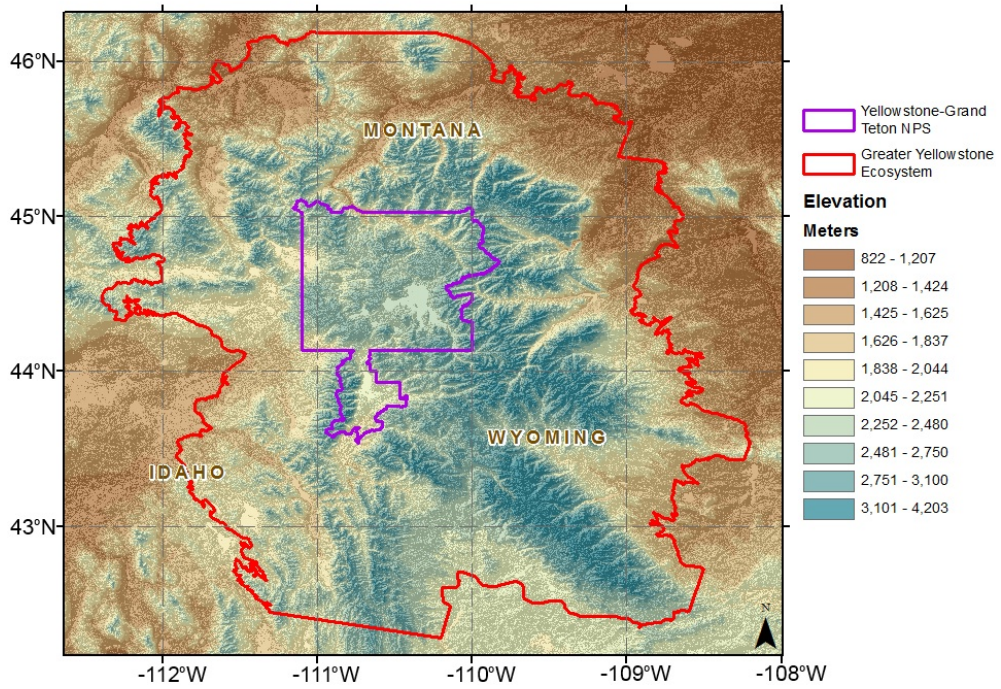

Climate
State-and-Transition
Simulation Modeling

Case Studies

Case Study #1: Whitebark Pine

Photo: http://en.wikipedia.org/



NORTH CENTRAL CLIMATE SCIENCE CENTER

Brian Miller

Colorado State University

Natural Resource Ecology Laboratory

Colorado State University

Leonardo Frid, Tony Chang, Nathan Piekielek, Andy Hansen, Jeff Morisette

APEX

MONTANA STATE UNIVERSITY

PENNSTATE 1855

USGS science for a changing world

Whitebark Pine (*Pinus albicaulis*)

Photo: http://en.wikipedia.org/

- Keystone species
- Listed candidate species

Photo: Jesse Logan

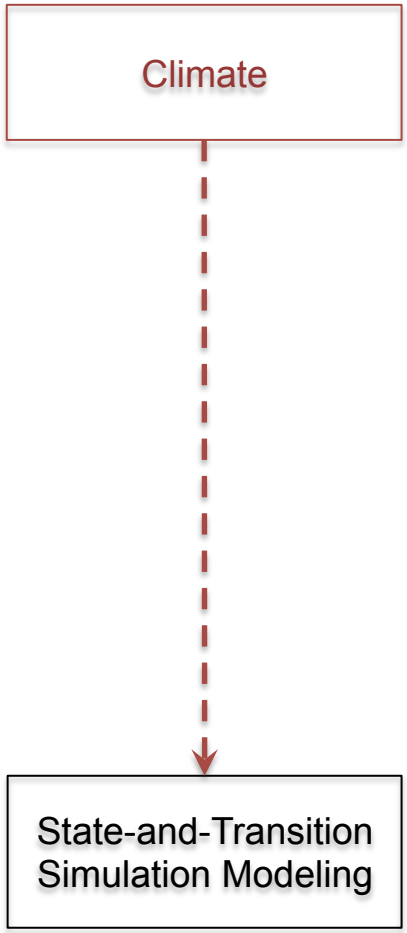
Slide: modified from Tony Chang

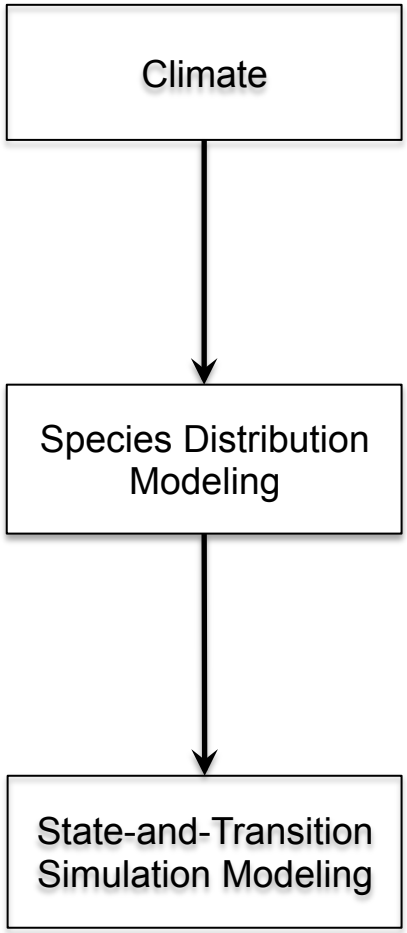
Whitebark Pine (*Pinus albicaulis*)

Photo: www.fs.fed.us/

Photo: Wilson Kern (nrdc.org/)

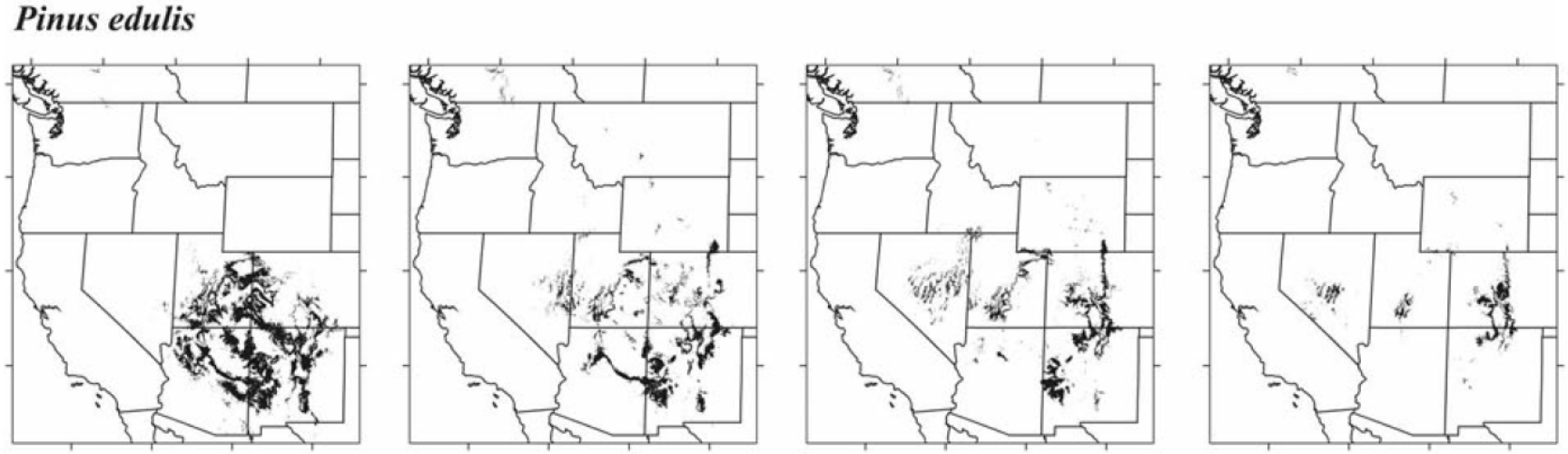
Photo: switchboard.nrdc.org/


Climate
State-and-Transition
Simulation Modeling


Climate
Species Distribution Modeling
State-and-Transition Simulation Modeling

Background: Species Distribution Modeling

- Correlative model of abiotic variables and species occurrence
- Does not project species distributions, but models projected suitable climates

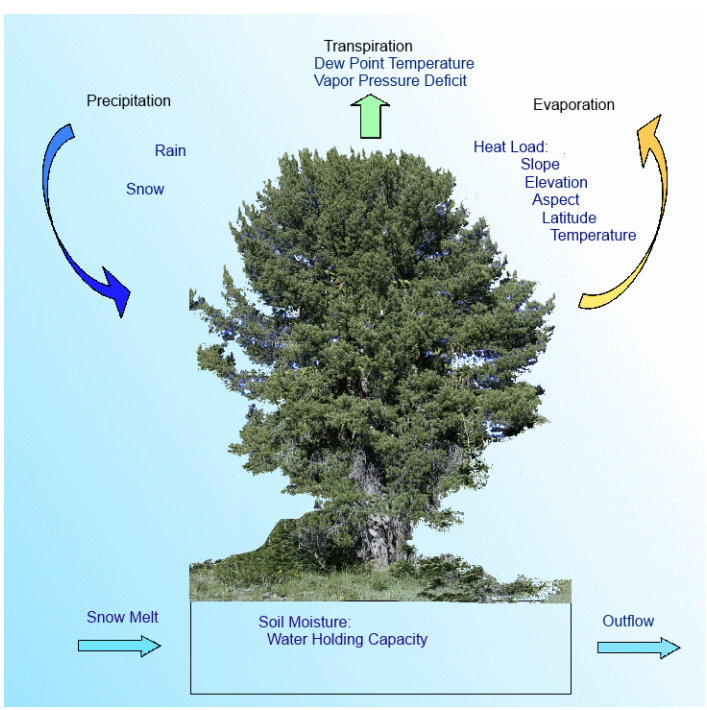


Slide: modified from Tony Chang

Figure: Rehfeldt et al 2006

Methods: Predictor Data

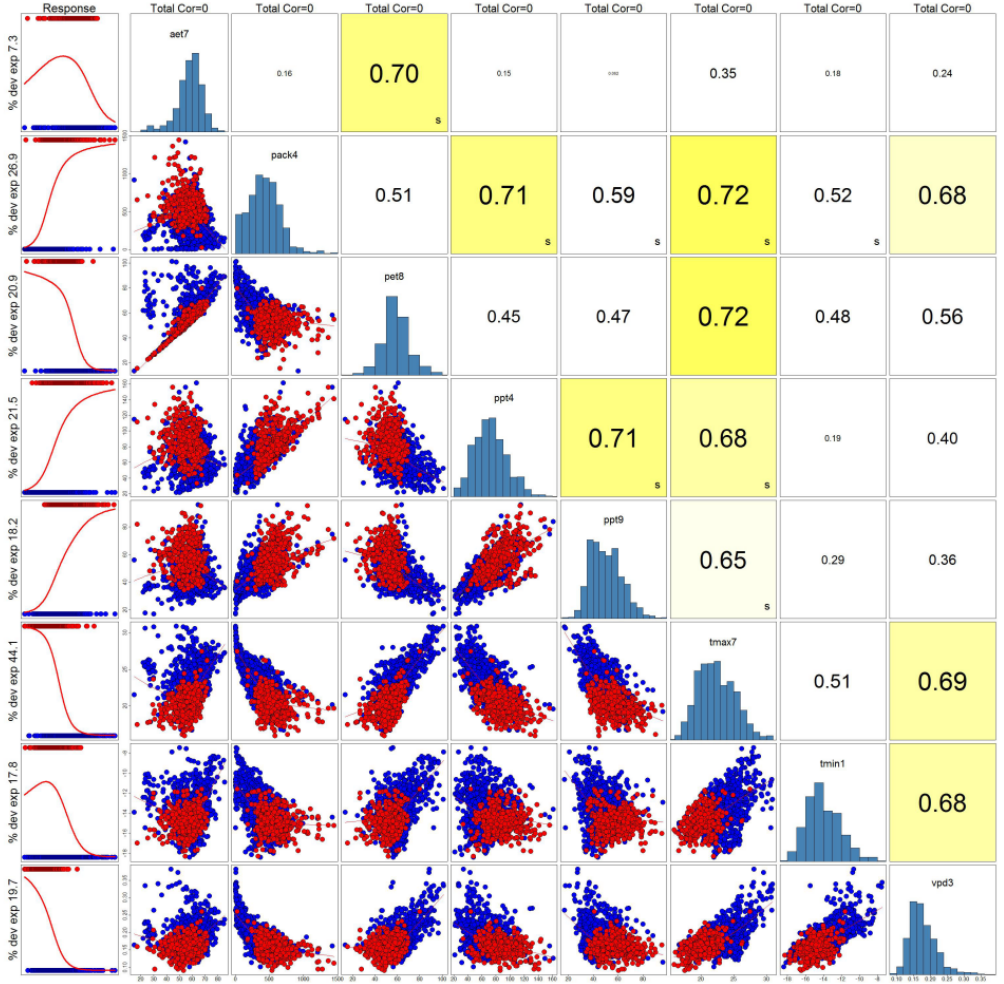
- Historic Climate Data
  - PRISM 800m climate
    - (Daly et al. 2011)
  - Monthly
  - Summarized using 1950-1980 means
- Water Balance Modeling
  - 10 additional metrics



Chang et al. 2014 *PLoS One*
Slide: Tony Chang

Methods: Predictor Selection

- 122 predictor covariates
- Suite considering ecologically meaningful predictors

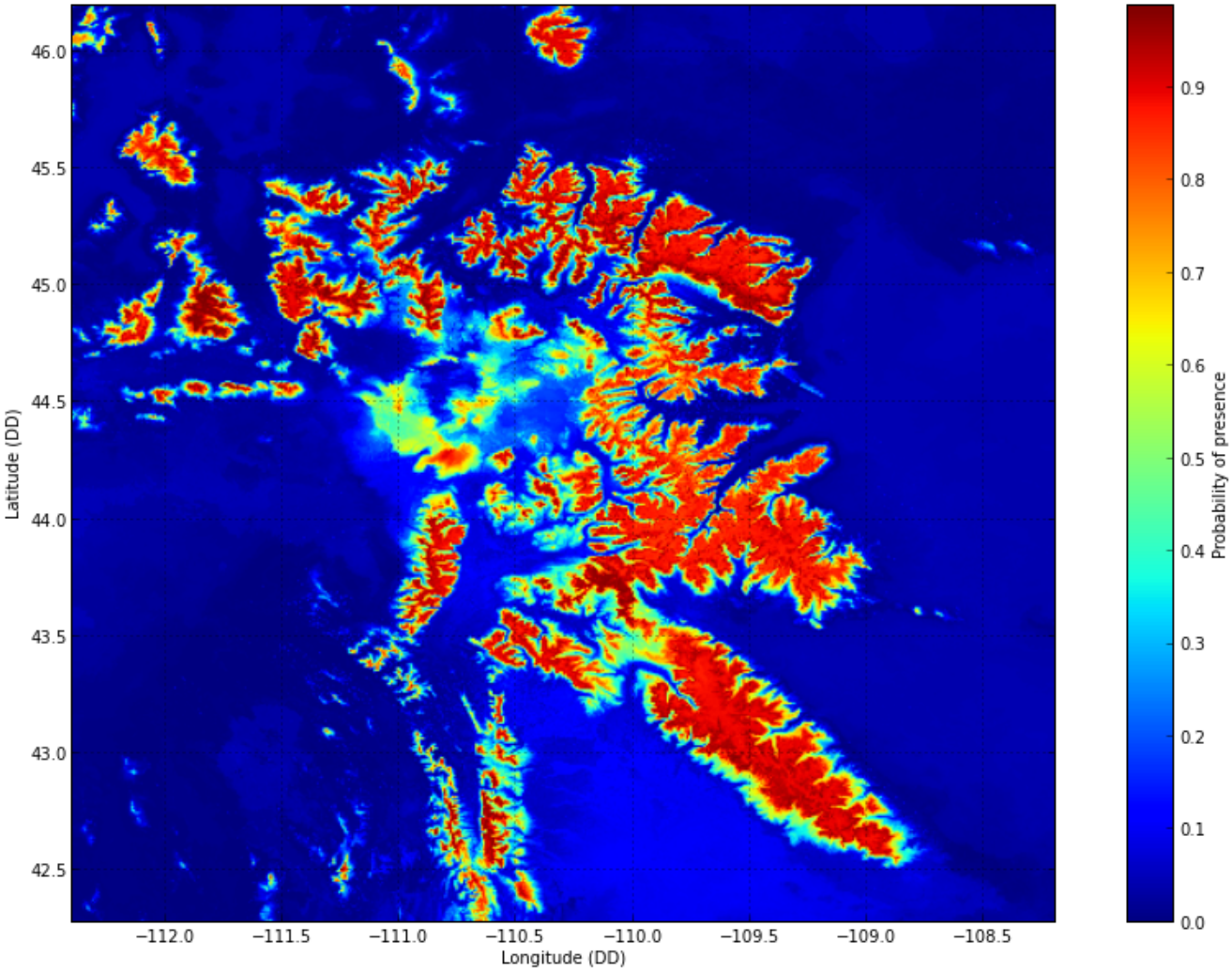


Chang et al. 2014 *PLoS One*
Slide: Tony Chang

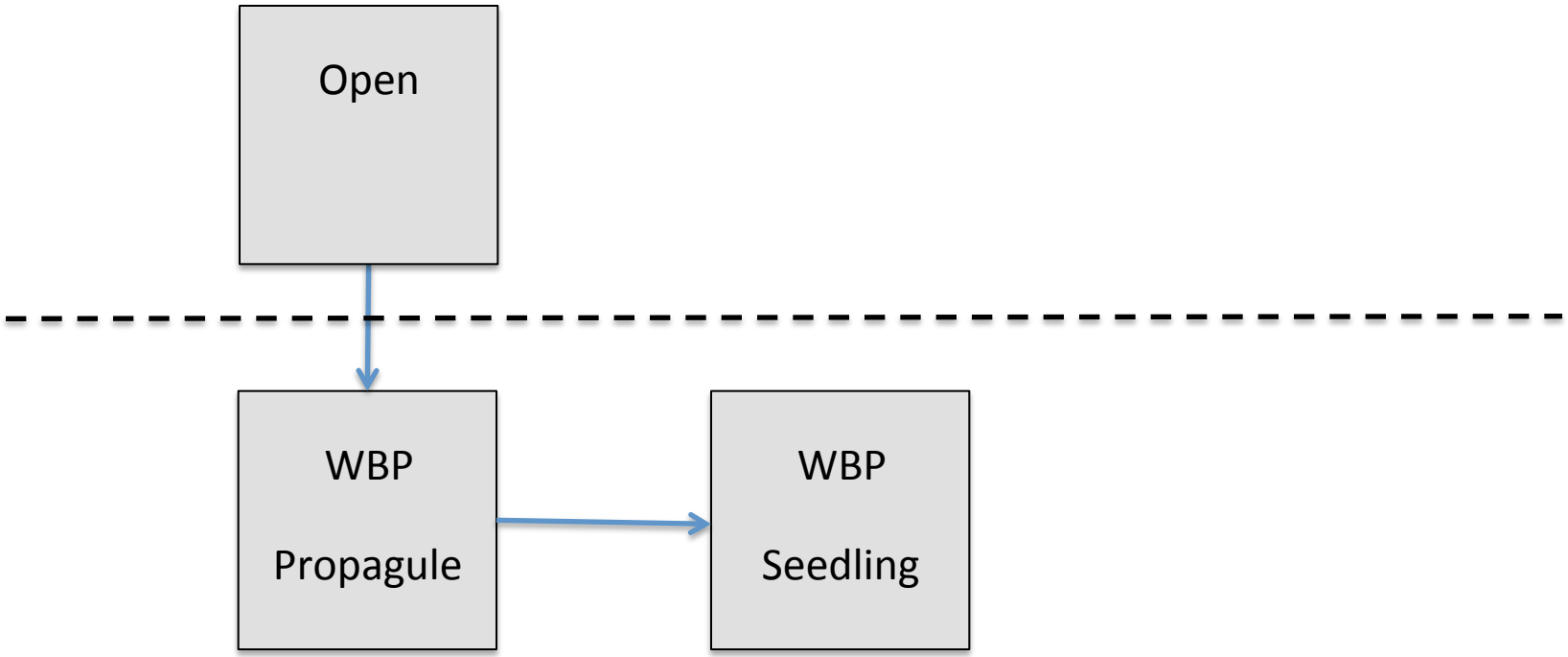
Methods: Model Algorithm

- Random Forest
- Historic runs: 1950-2010
- Projections: 2010-2100
  - RCP 4.5, 8.5
  - GCMs: CNRM-CM5, HadGEM2-AO

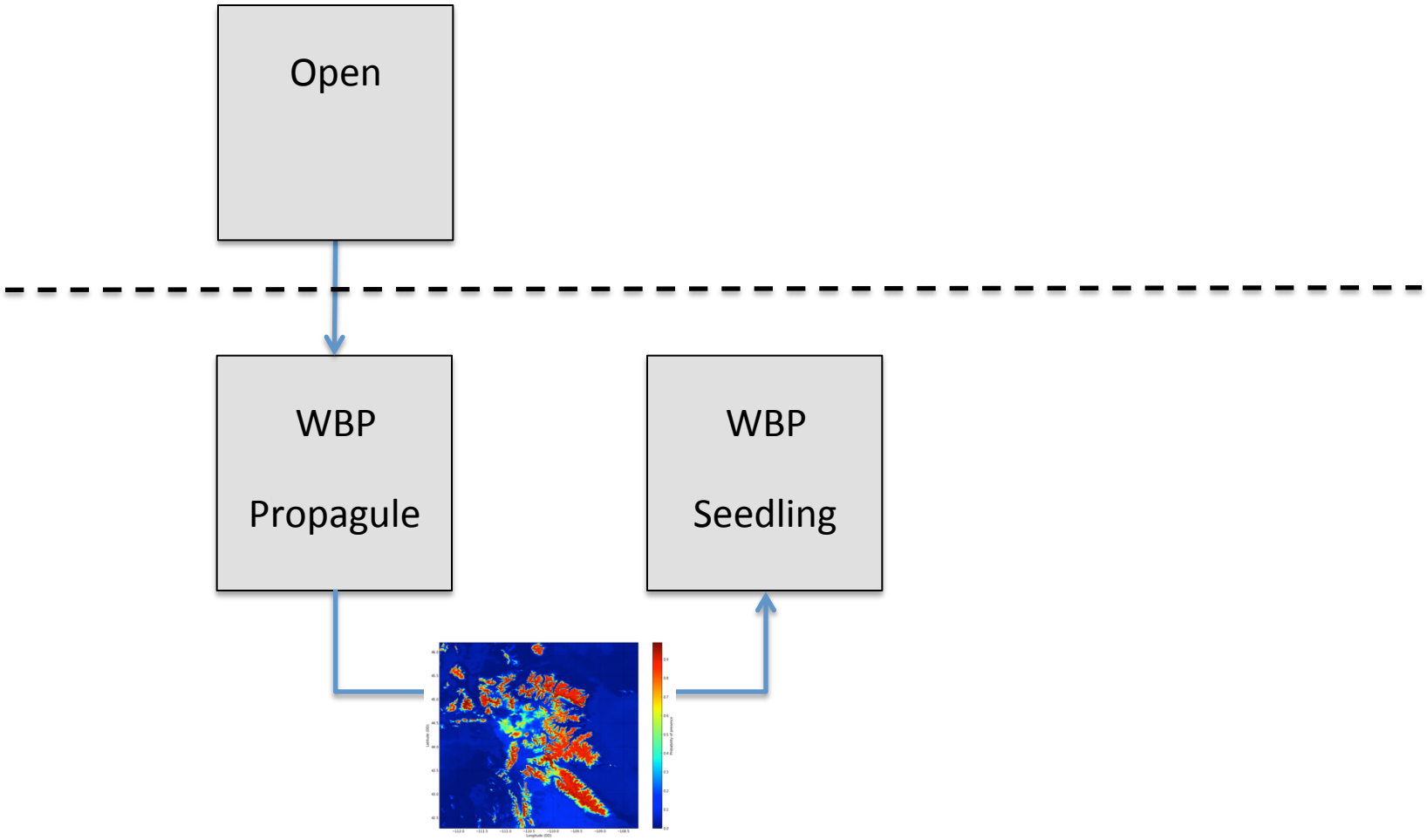
Species Distribution Model Results



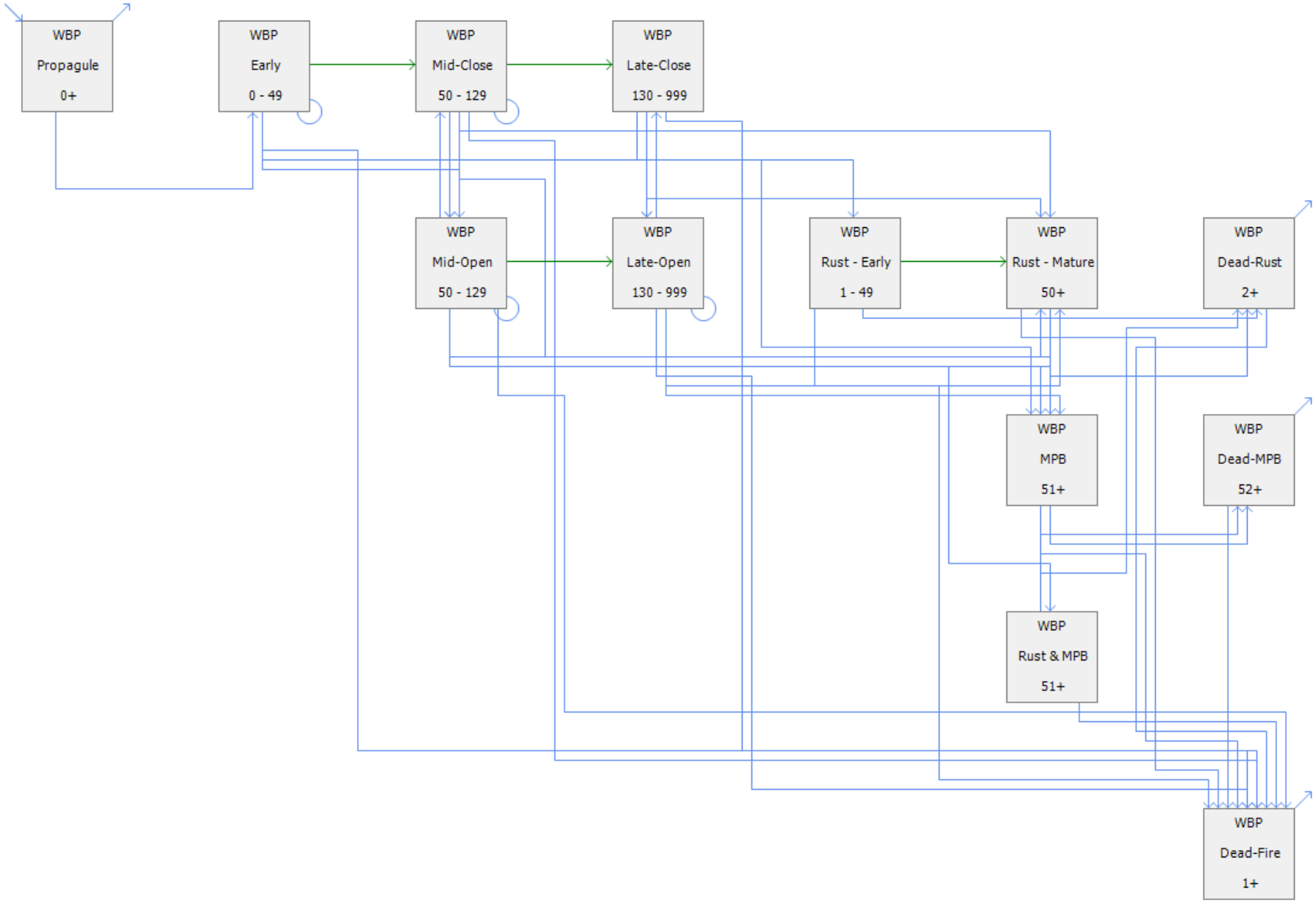
Basic Structure of State-and-Transition Simulation



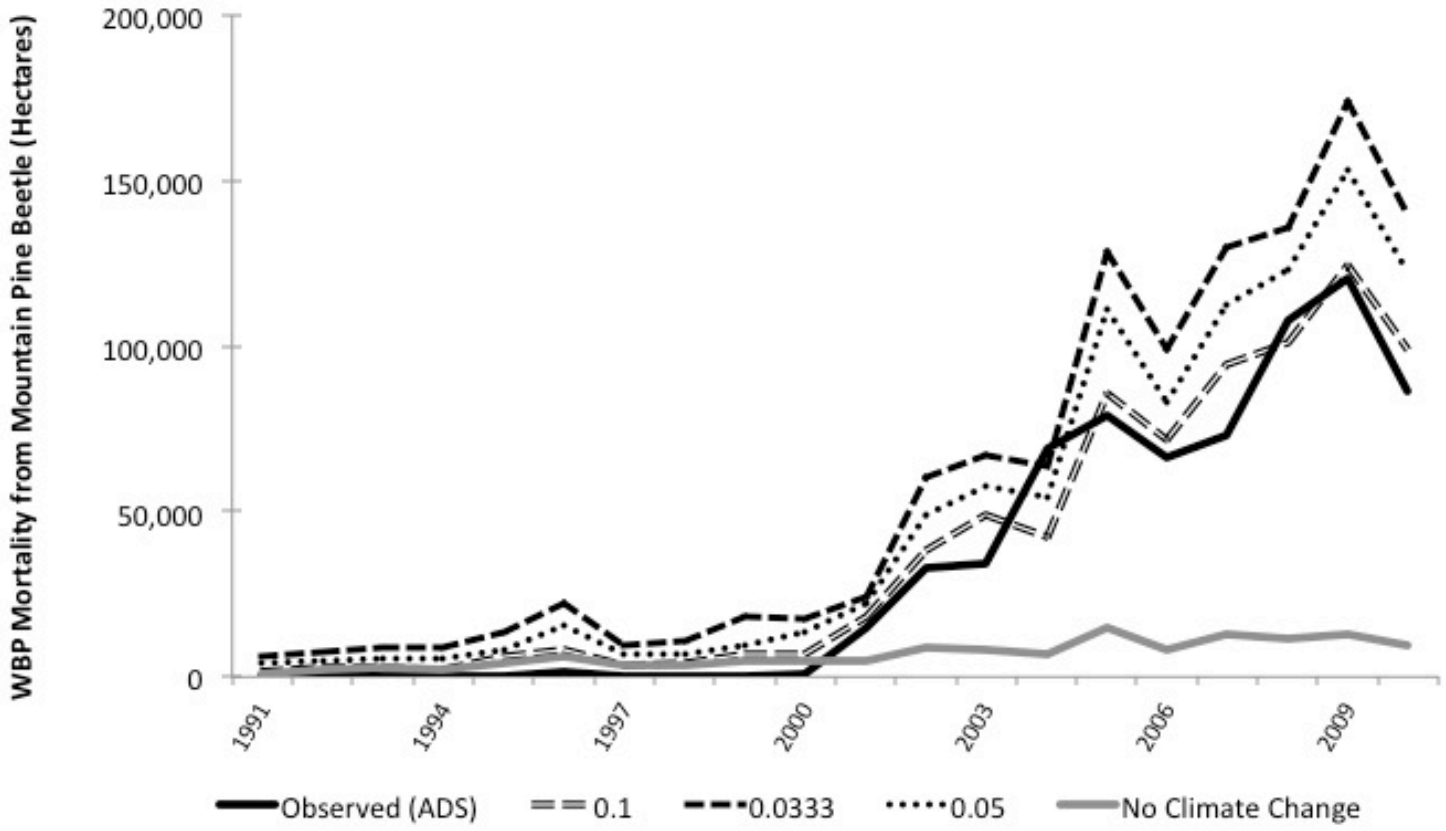
Basic Structure of State-and-Transition Simulation



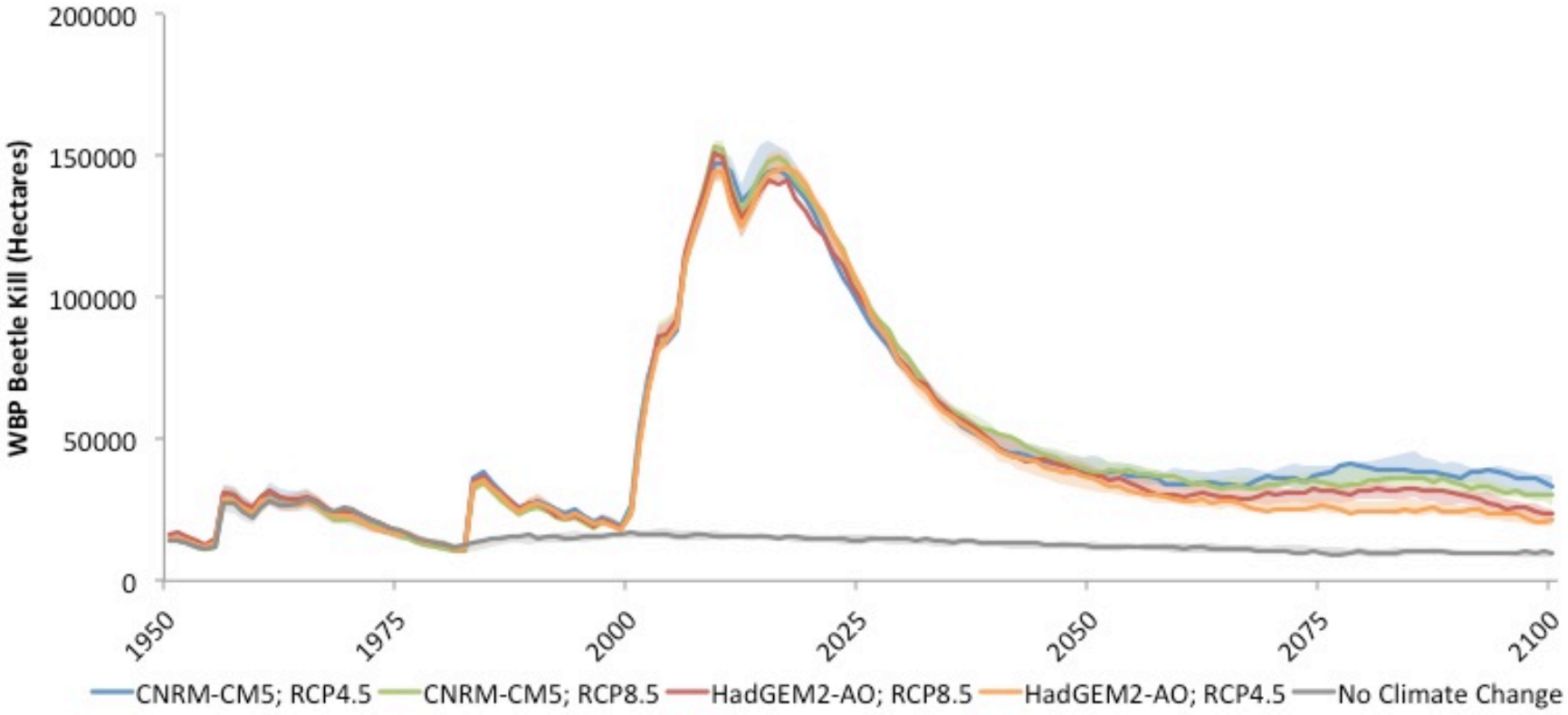
Spatial Multiplier = Habitat Suitability


WBP
Propagule
0+
WBP
Early
0 - 49
WBP
Mid-Close
50 - 129
WBP
Late-Close
130 - 999
WBP
Mid-Open
50 - 129
WBP
Late-Open
130 - 999
WBP
Rust - Early
1 - 49
WBP
Rust - Mature
50+
WBP
Dead-Rust
2+
WBP
MPB
51+
WBP
Dead-MPB
52+
WBP
Rust & MPB
51+
WBP
Dead-Fire
1+

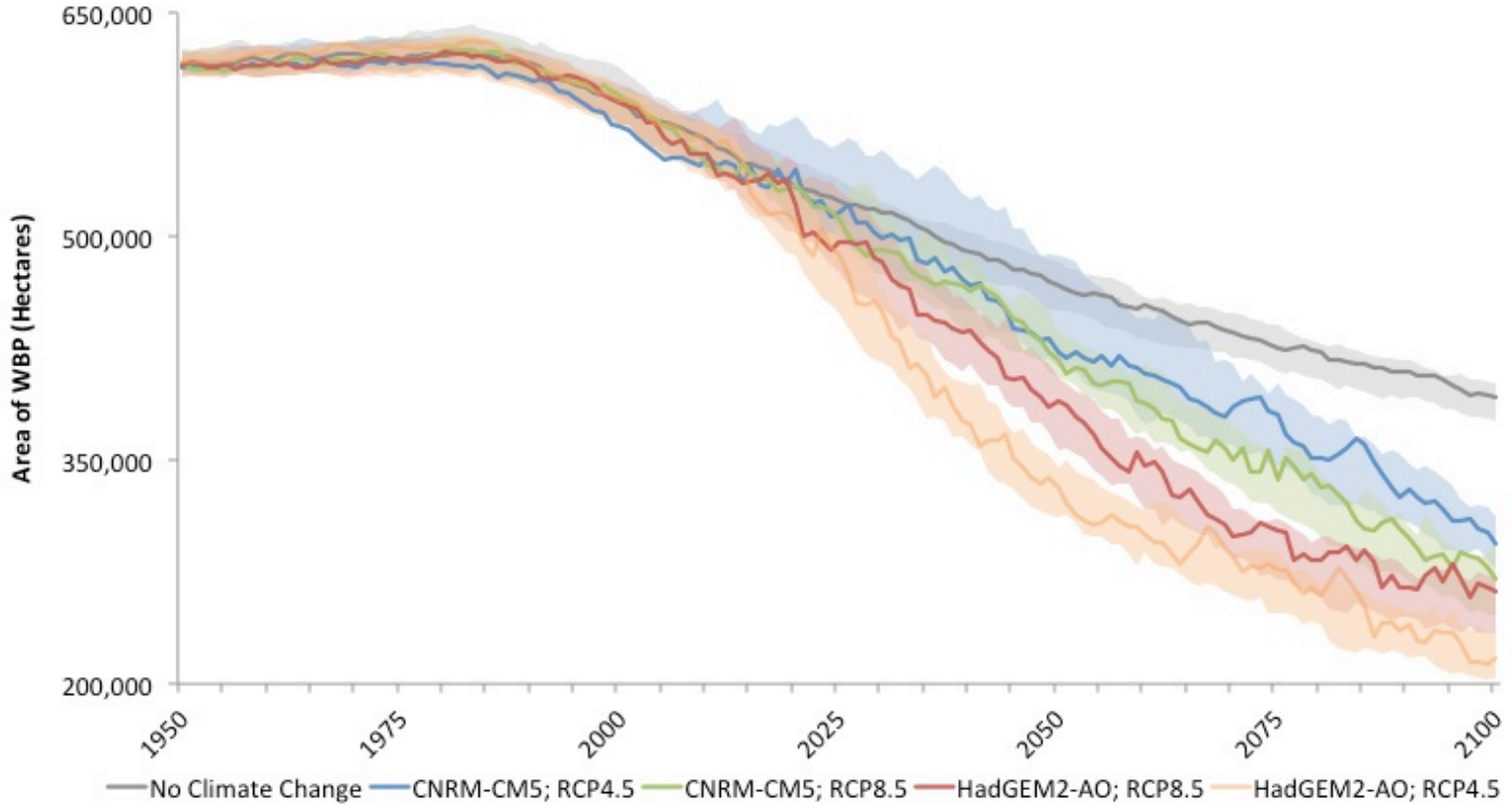
Validation


WBP Mortality from Mountain Pine Beetle (Hectares)
200,000
150,000
100,000
50,000
0
1991
1994
1997
2000
2003
2006
2009
Observed (ADS)
0.1
0.0333
0.05
No Climate Change

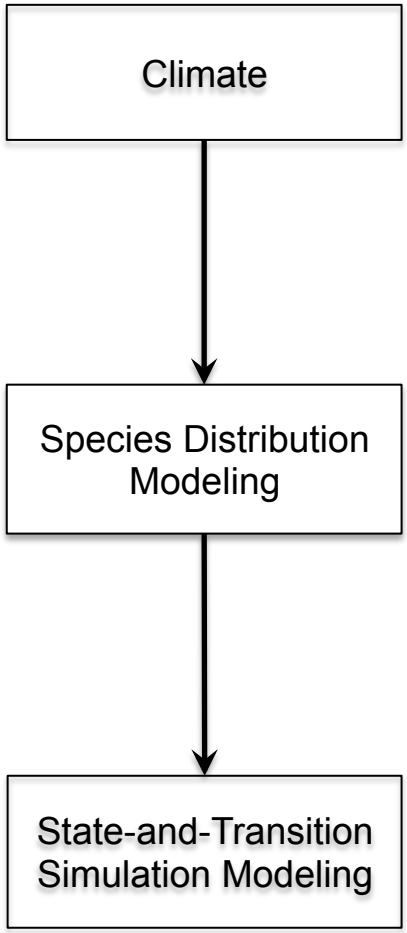
Results

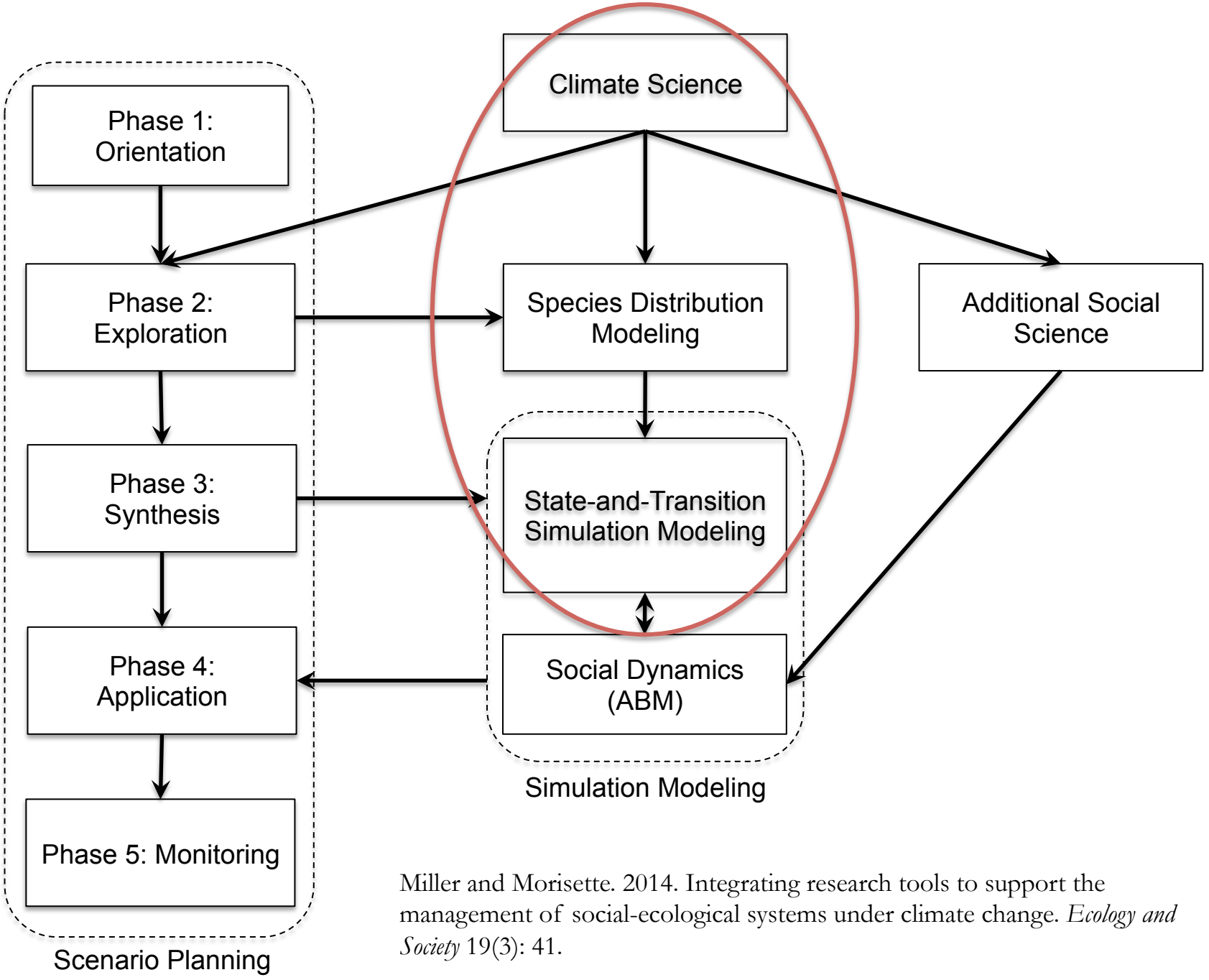

WBP Beetle Kill (Hectares)
200000
150000
100000
50000
0
1950
1975
2000
2025
2050
2075
2100
CNRM-CM5; RCP4.5
CNRM-CM5; RCP8.5
HadGEM2-AO; RCP8.5
HadGEM2-AO; RCP4.5
No Climate Change

Results



Miller, BW, L Frid, T Chang, N Piekielek, AJ Hansen, JT Morisette. Forthcoming. Combining state-and-transition simulations and species distribution models to anticipate the effects of climate change. *AIMS Environmental Science*.

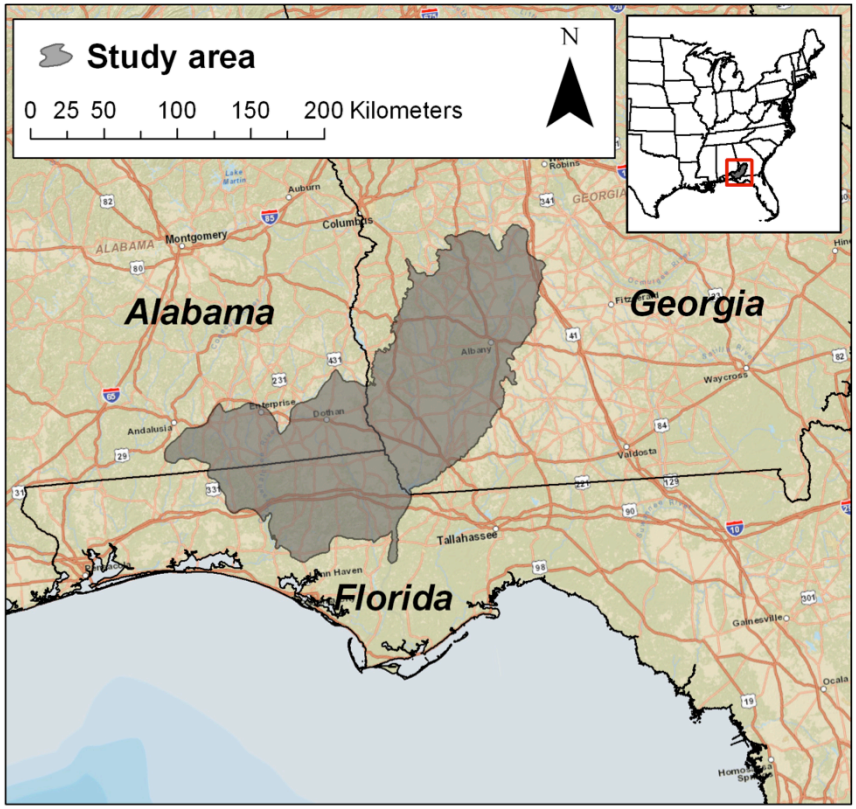

Climate
Species Distribution Modeling
State-and-Transition Simulation Modeling



Miller and Morisette. 2014. Integrating research tools to support the management of social-ecological systems under climate change. *Ecology and Society* 19(3): 41.

Outline

Case Study #2: Longleaf Pine



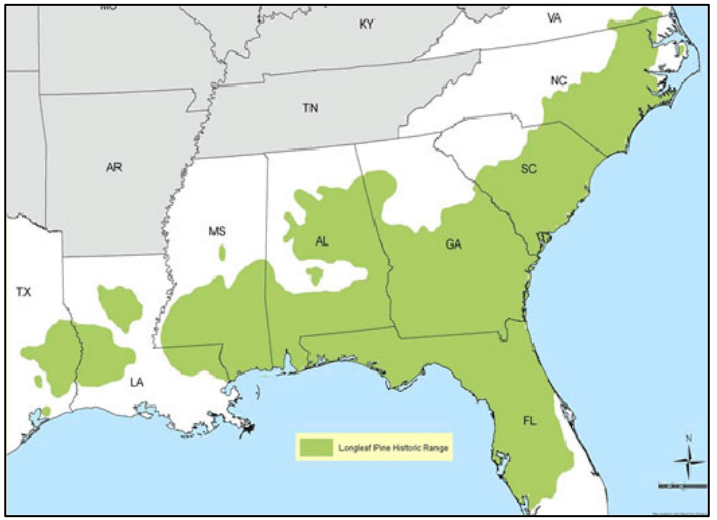
Jennifer Costanza
North Carolina State University

DEPARTMENT of the INTERIOR
SE CLIMATE SCIENCE CENTER

USGS science for a changing world

gap KEEPING COMMON SPECIES COMMON

The longleaf pine ecosystem



Conservation goals and strategies for longleaf

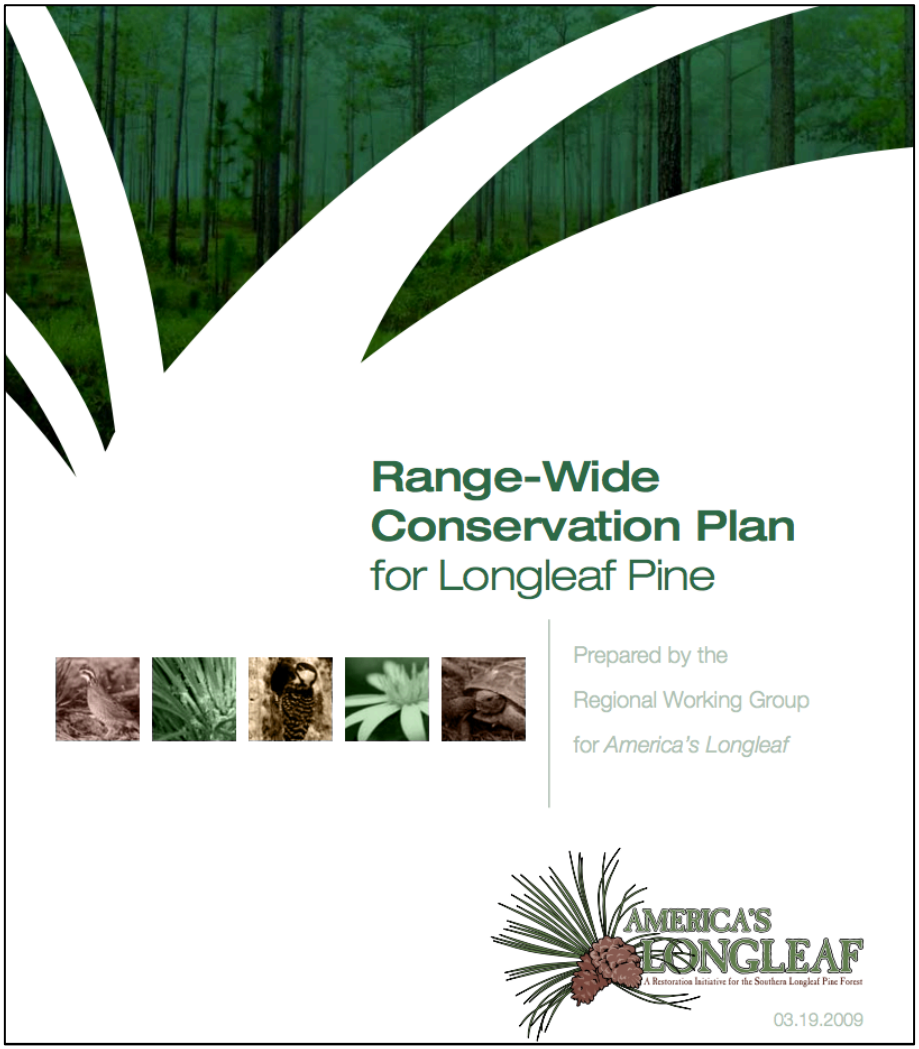
America's Longleaf report (2009)

Increase the total area of longleaf by 135%

Double the area of open longleaf

Focus on maintaining open stands

Also improve and restore degraded stands

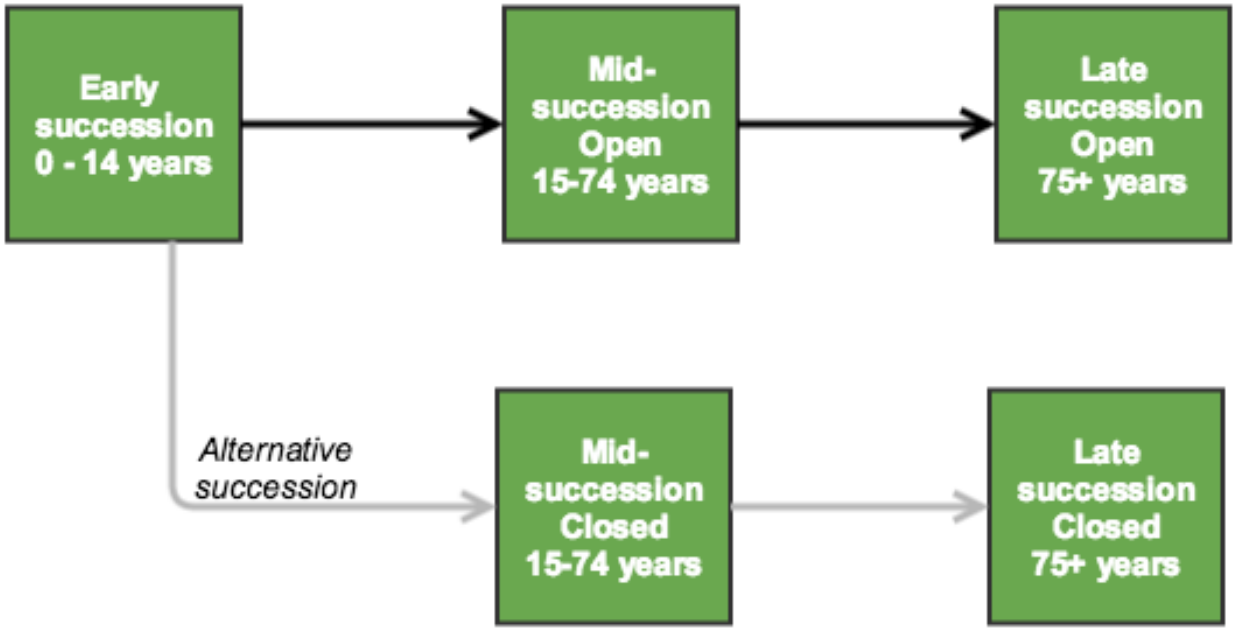


Research question

Over the next century, will conservation goals for longleaf be met under scenarios of:

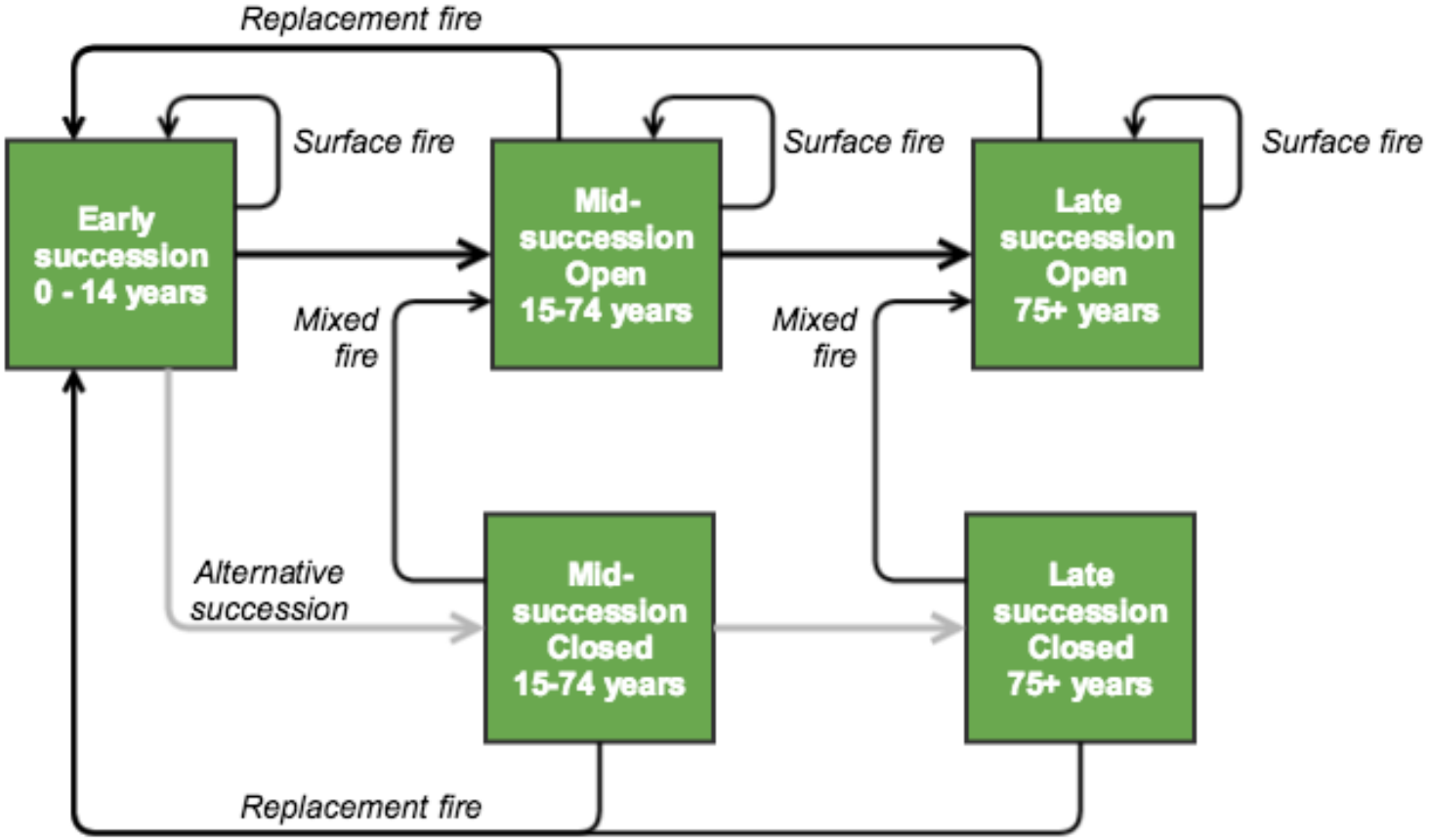
- Climate change
- Urbanization
- Potential management

State-and-transition model for the longleaf pine ecosystem



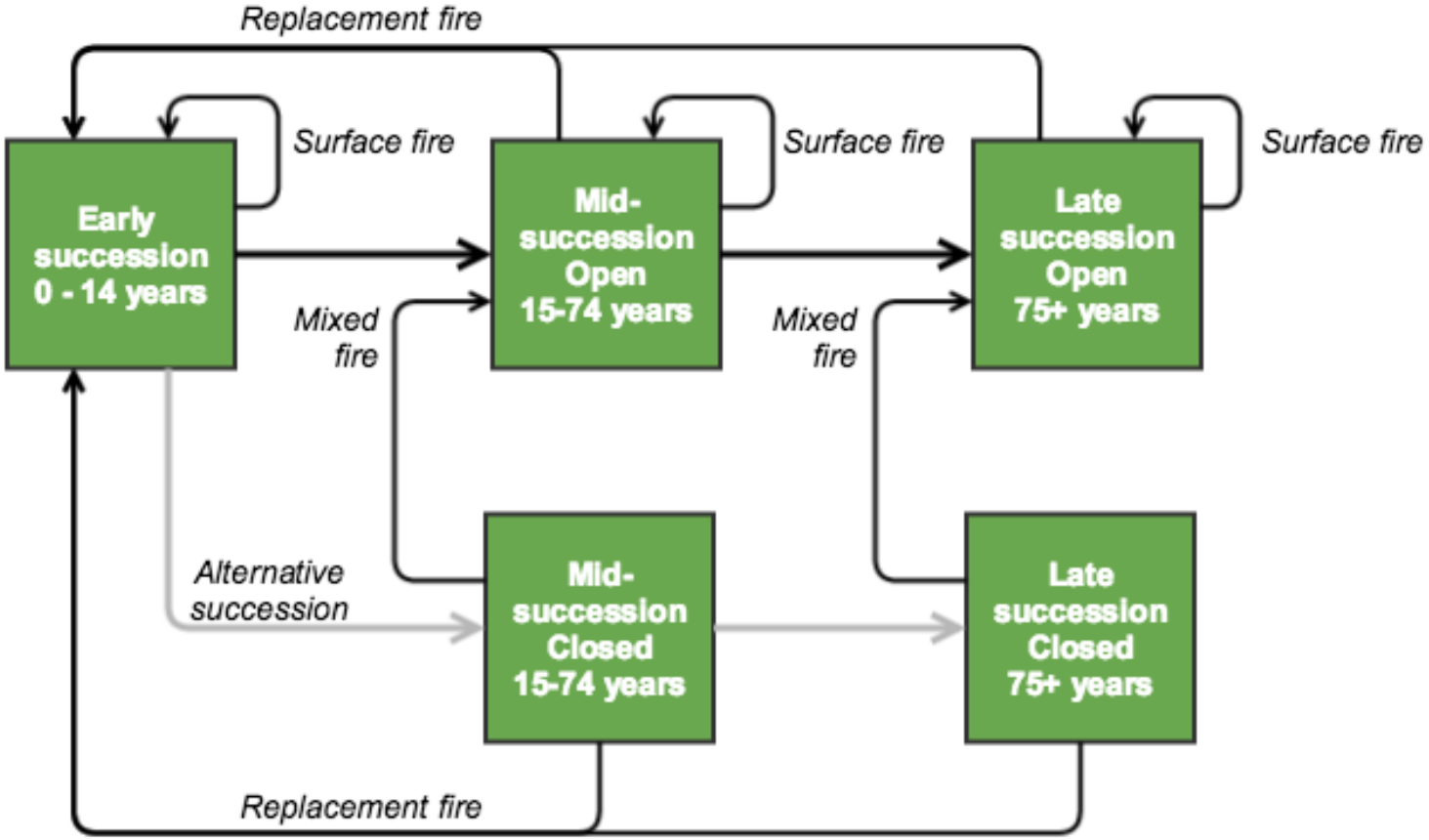
LANDFIRE vegetation dynamics model

State-and-transition model for the longleaf pine ecosystem



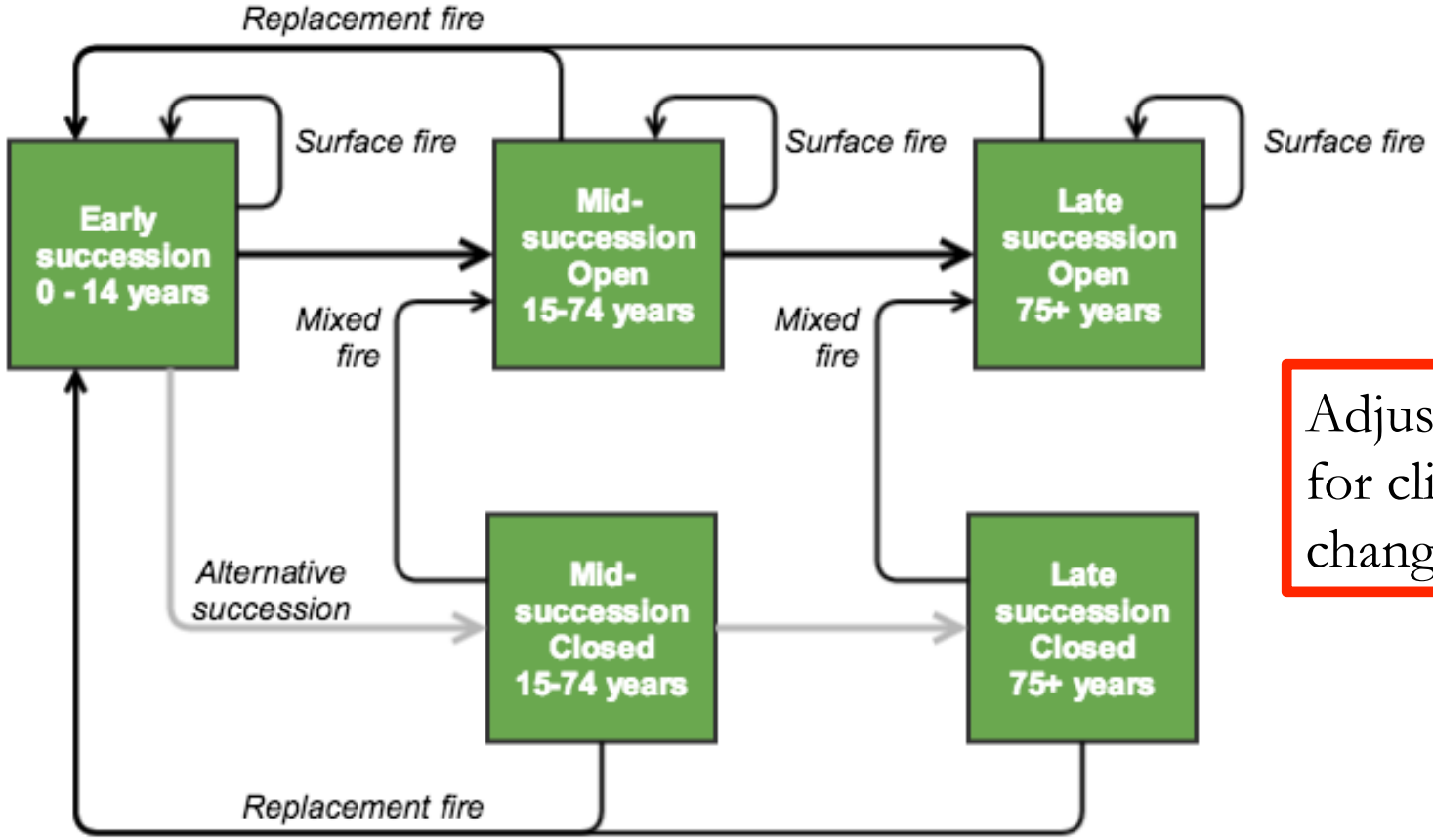
LANDFIRE vegetation dynamics model

State-and-transition model for the longleaf pine ecosystem



Wildfire probabilities:	Surface fire	0.02
	Mixed fire	0.0004
	Replacement fire	0.0006

State-and-transition model for the longleaf pine ecosystem



Adjust all for climate change

Wildfire probabilities:	Surface fire	0.02
	Mixed fire	0.0004
	Replacement fire	0.0006

Climate change effect on wildfires

Wildfire and climate data

Regression

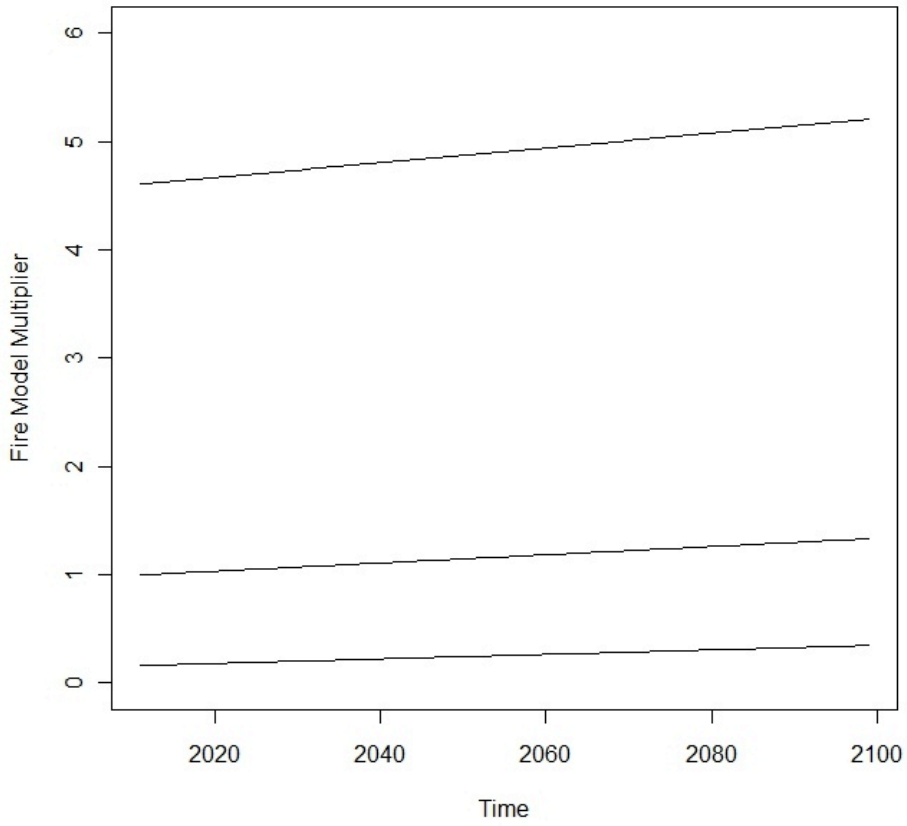
Recent Area burned =
f(recent climate)

Future area burned =
f(K. Hayhoe downscaled climate projections 2012-2100)

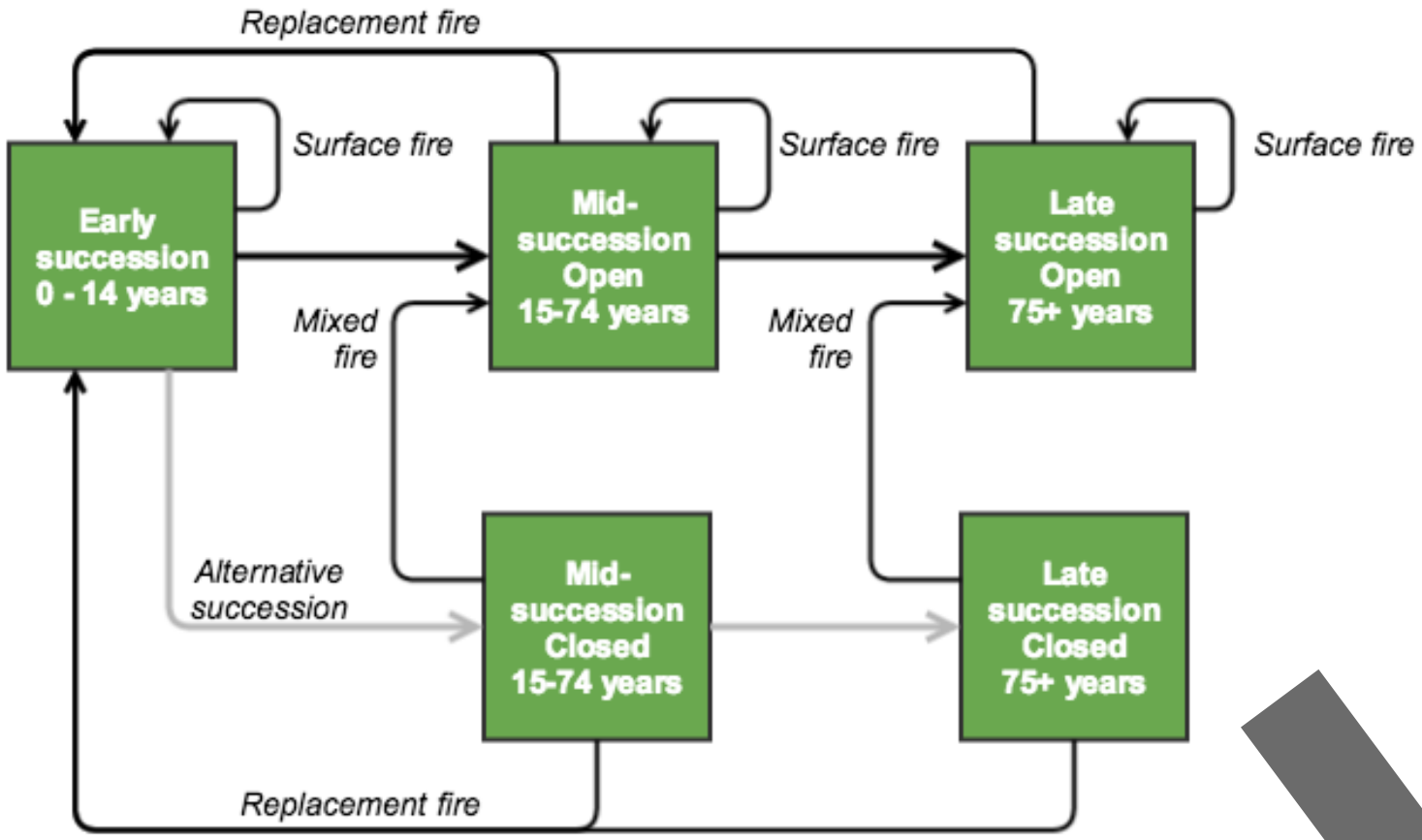
Applied as time series of wildfire probability multipliers over time: A1FI and B1 scenarios

50 Monte Carlo simulations

A1FI scenario

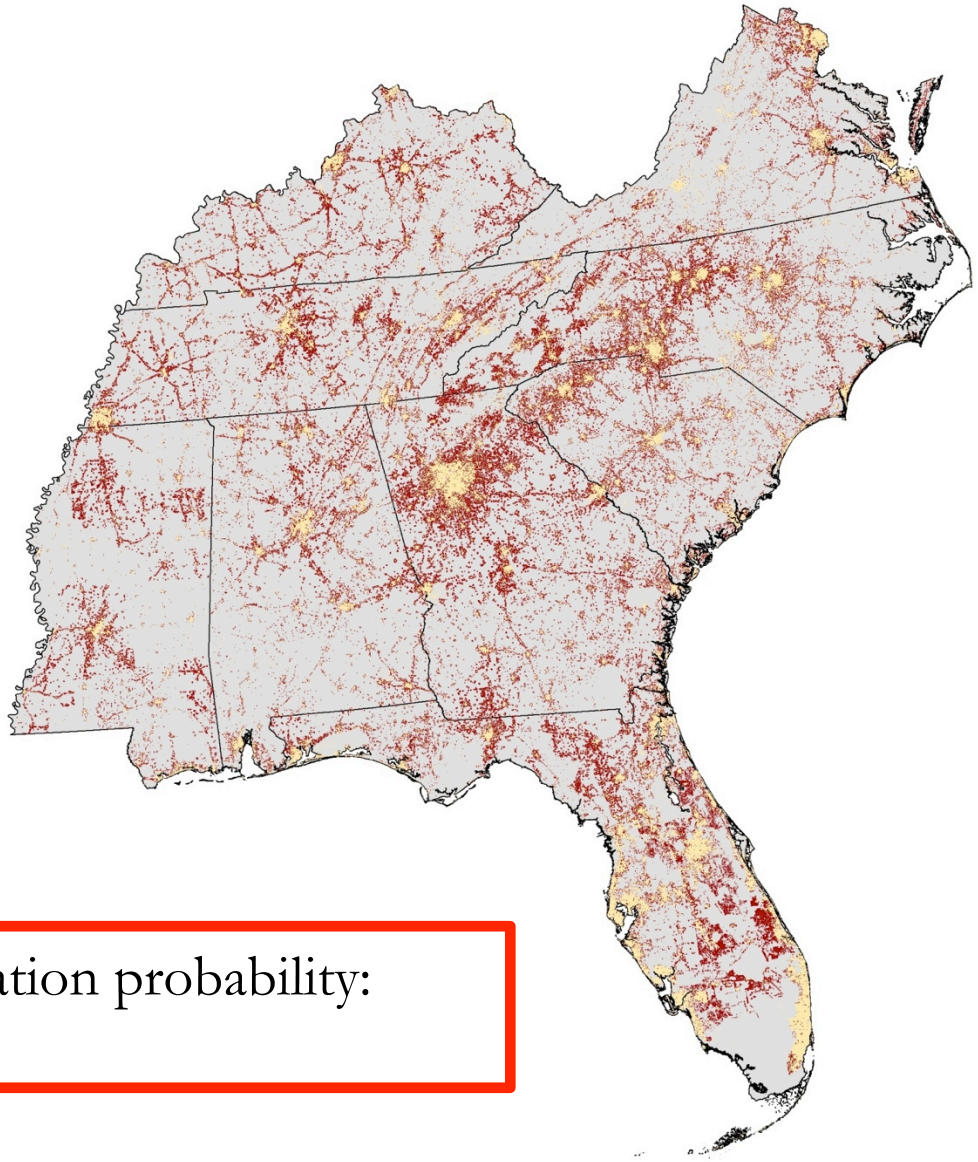


Adding urbanization



To urban

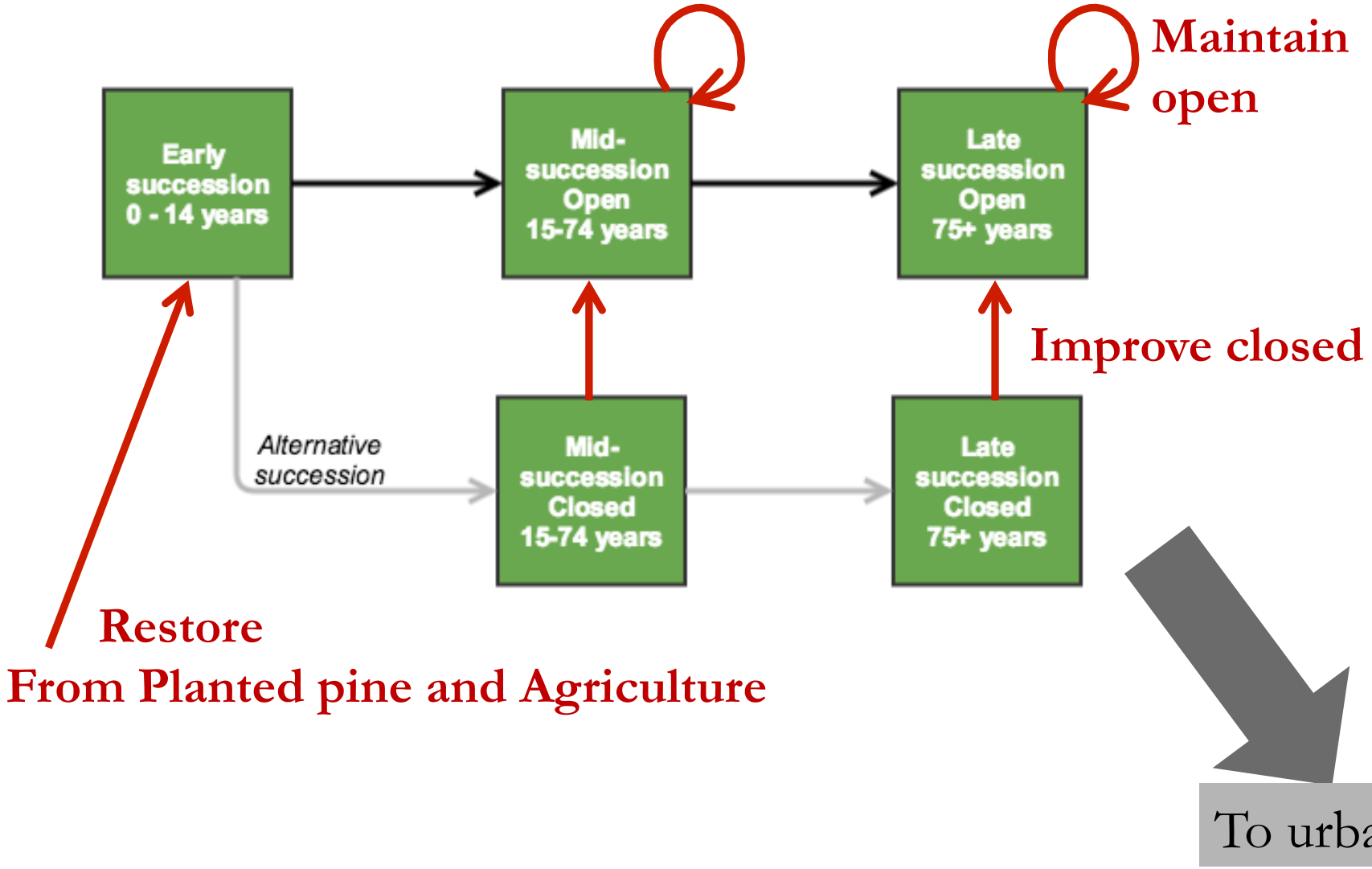
Urbanization



Annual urbanization probability:
0.0018

Terando et al. 2014 *PLOS ONE*

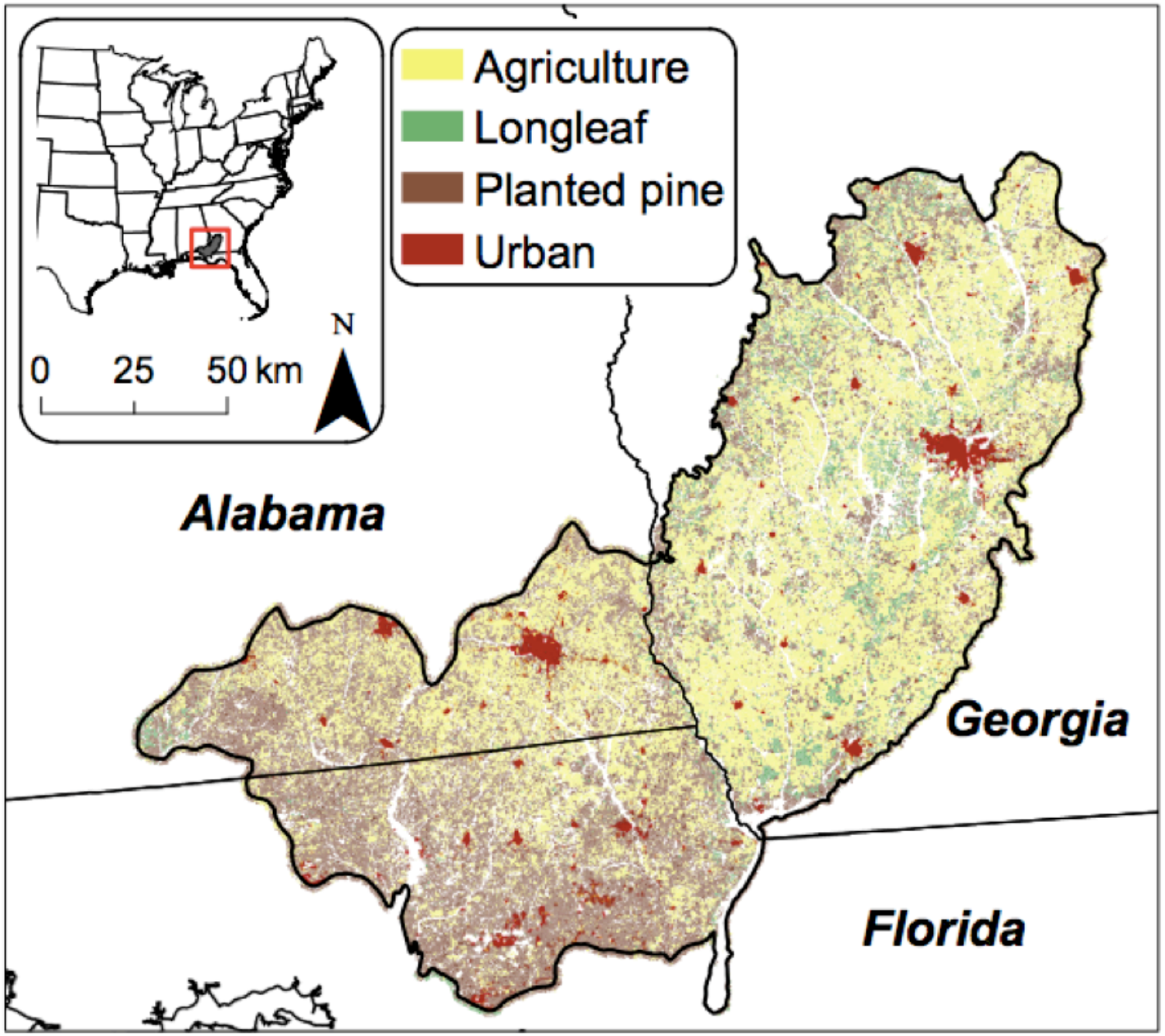
Adding management transitions



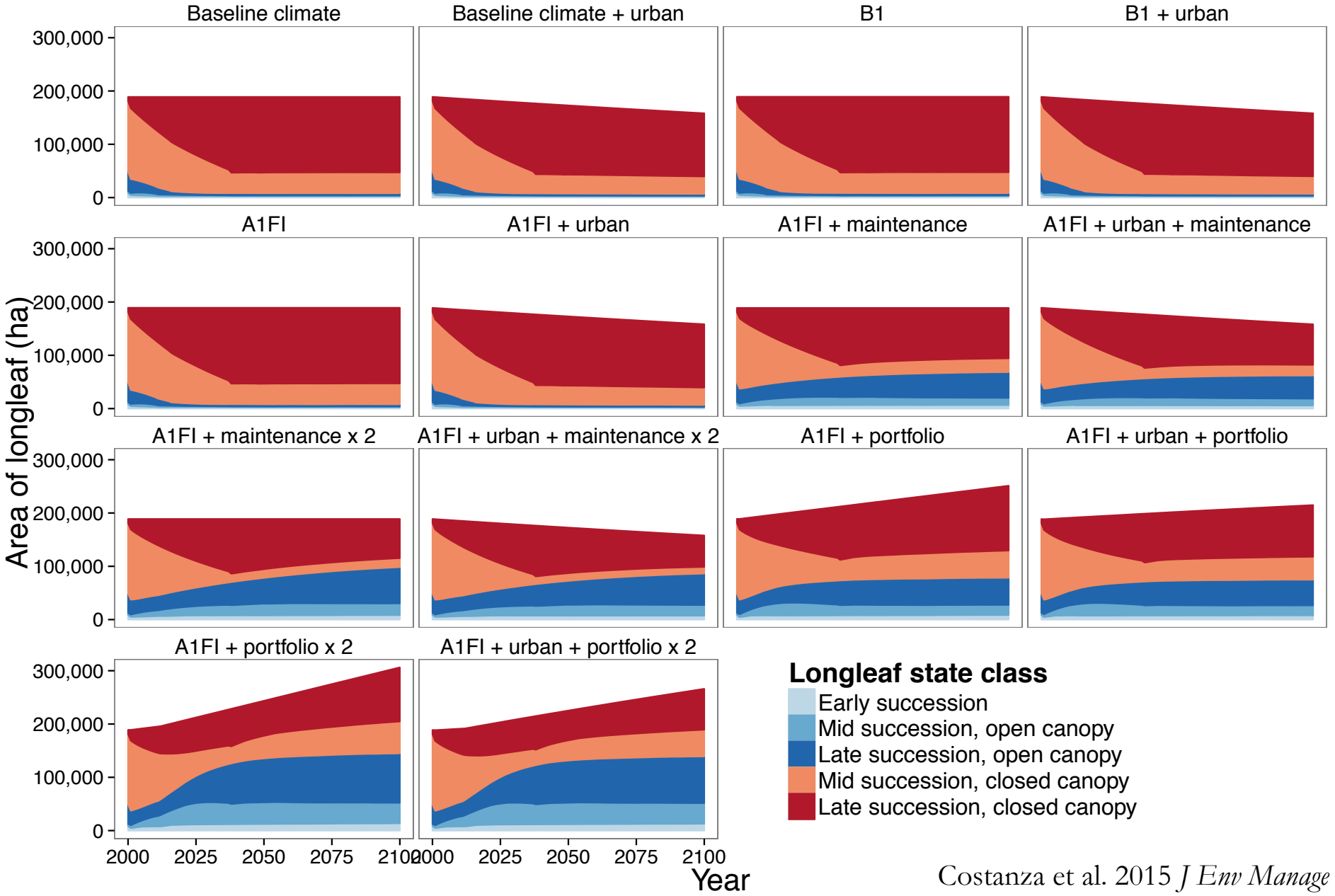
Scenarios (14)

	Without urbanization	With urbanization
Climate only	No climate, no management	No climate, no management, urban
	A1FI climate (high emissions)	A1FI climate (high emissions), urban
	B1 climate (low emissions)	B1 climate (low emissions), urban
With management	A1FI, Maintenance burning	A1FI, Maintenance burning, urban
	A1FI, Maintenance burning x 2	A1FI, Maintenance burning x 2, urban
	A1FI, Management portfolio	A1FI, Management portfolio, urban
	A1FI, Management portfolio x 2	A1FI, Management portfolio x 2, urban

Initial (2001) landscape

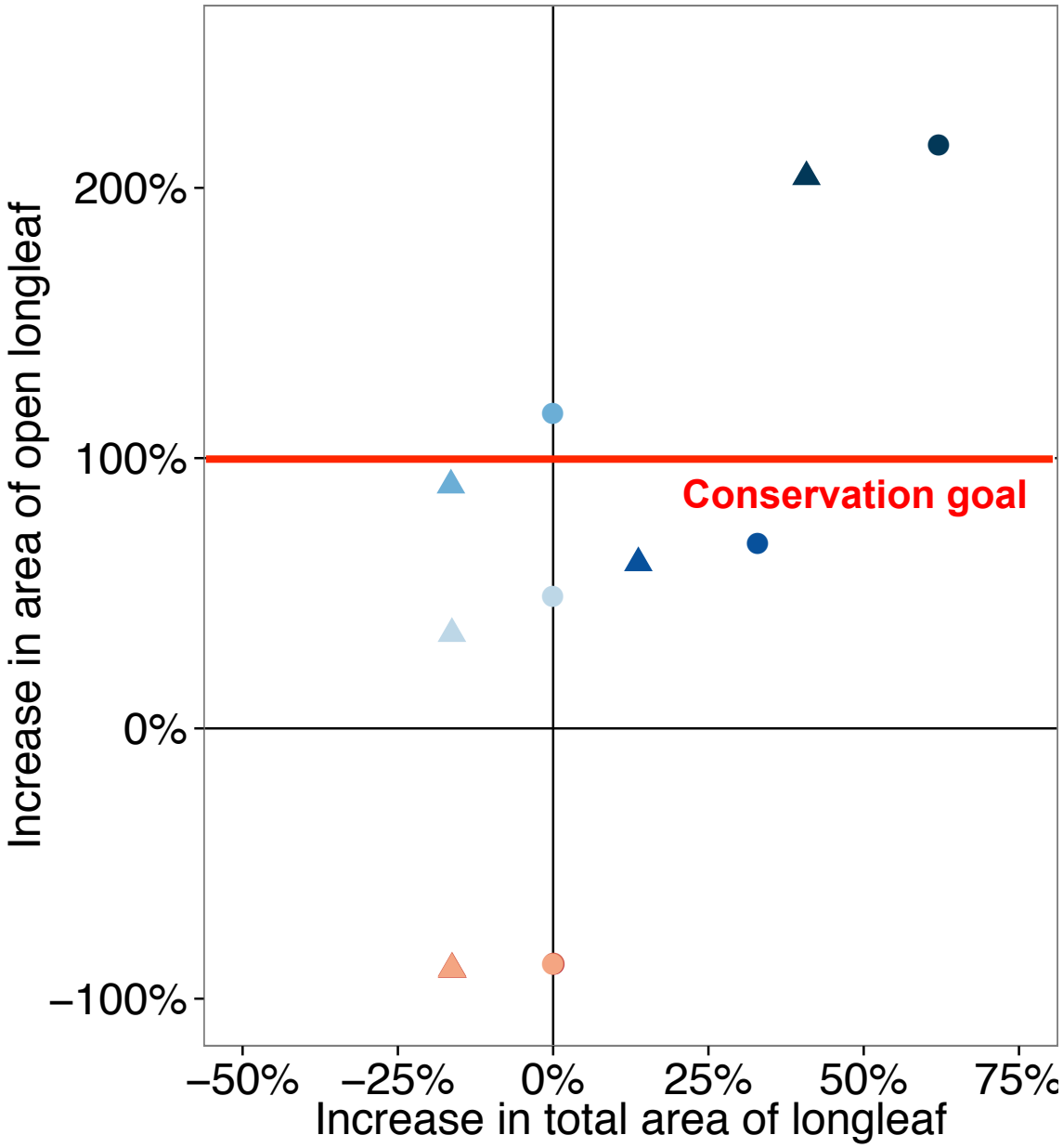


Results: Longleaf state classes over time



Costanza et al. 2015 *J Env Manage*

Results: Change in longleaf area at 2100



Mgmt. portfolio x 2

Maintenance only x 2

Mgmt. portfolio

Maintenance only

Climate-only scenarios

Costanza et al. 2015 *J Env Manage*

Outline

Case Study #3: Rangeland Condition and Sage-Grouse Habitat

Megan Creutzburg
Institute for Natural Resources

Institute for Natural Resources

OSU Oregon State University

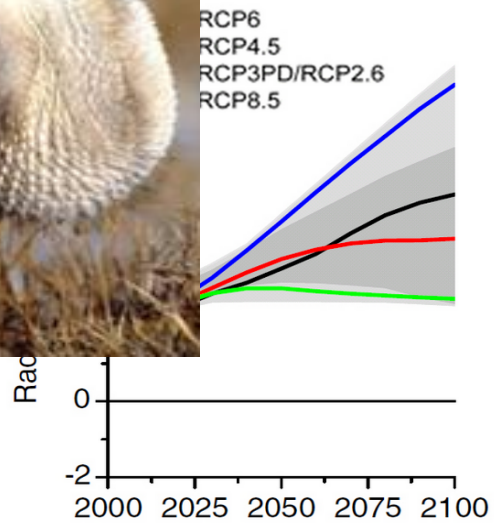
Portland State University

NW CSC Northwest Climate Science Center

Southeast Oregon

Cool-moist shrub steppe

Warm-dry shrub steppe



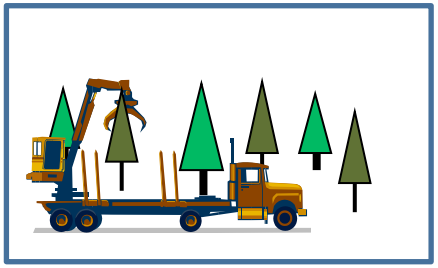
IPCC

Objectives

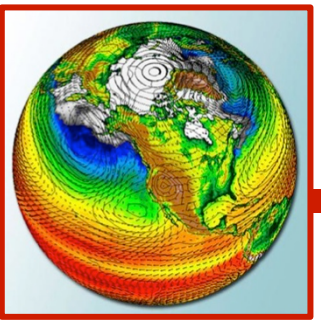
- Model vegetation change into the future under varying scenarios of climate and management
- Interpret implications for vegetation condition and sage-grouse habitat

Integrating Models

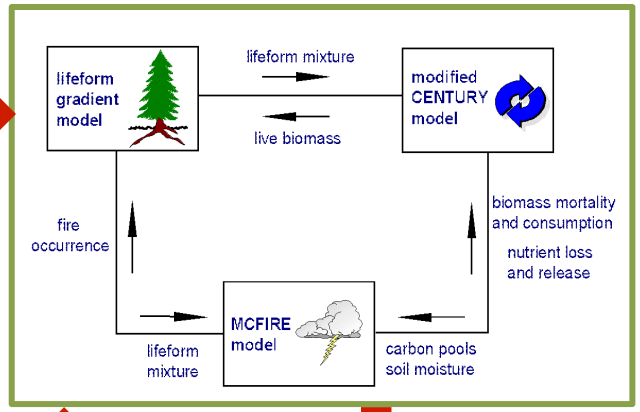
Management Scenarios



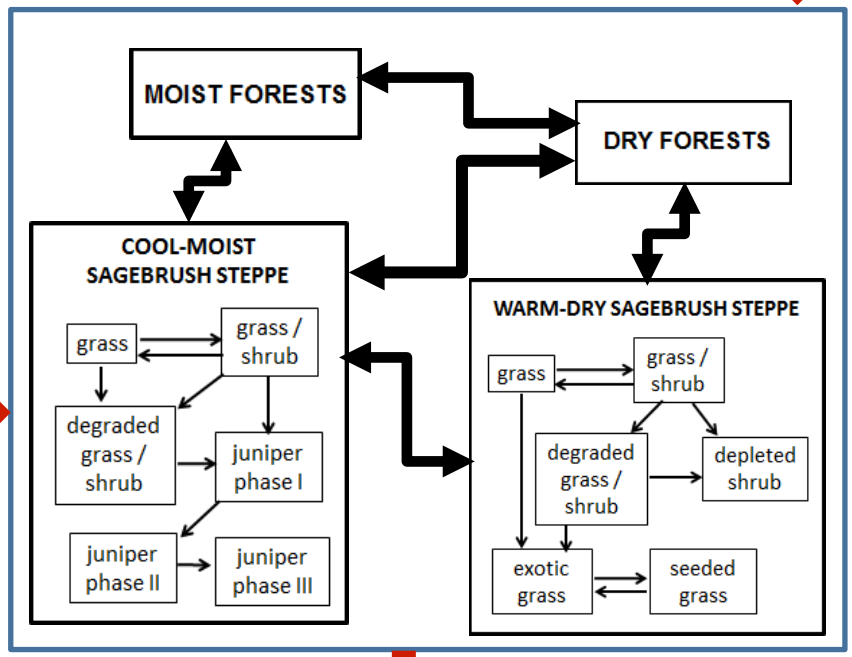
Climate Scenarios



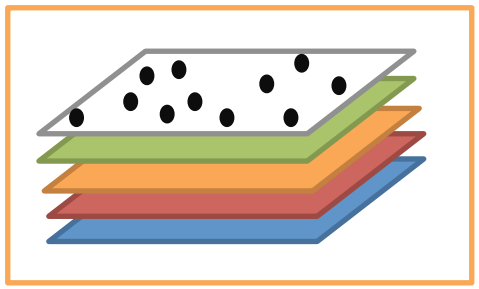
MC2 Dynamic Global Vegetation Model



Climate-informed State-and-Transition Simulation Models

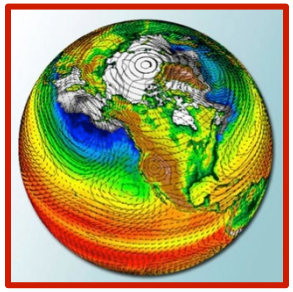


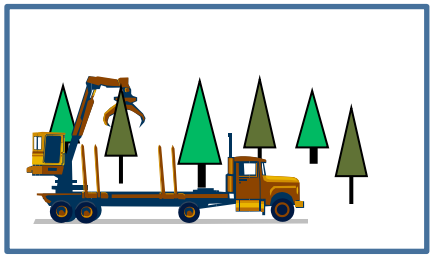
Sage-Grouse Species Distribution Model



Sage-Grouse Habitat

Scenarios

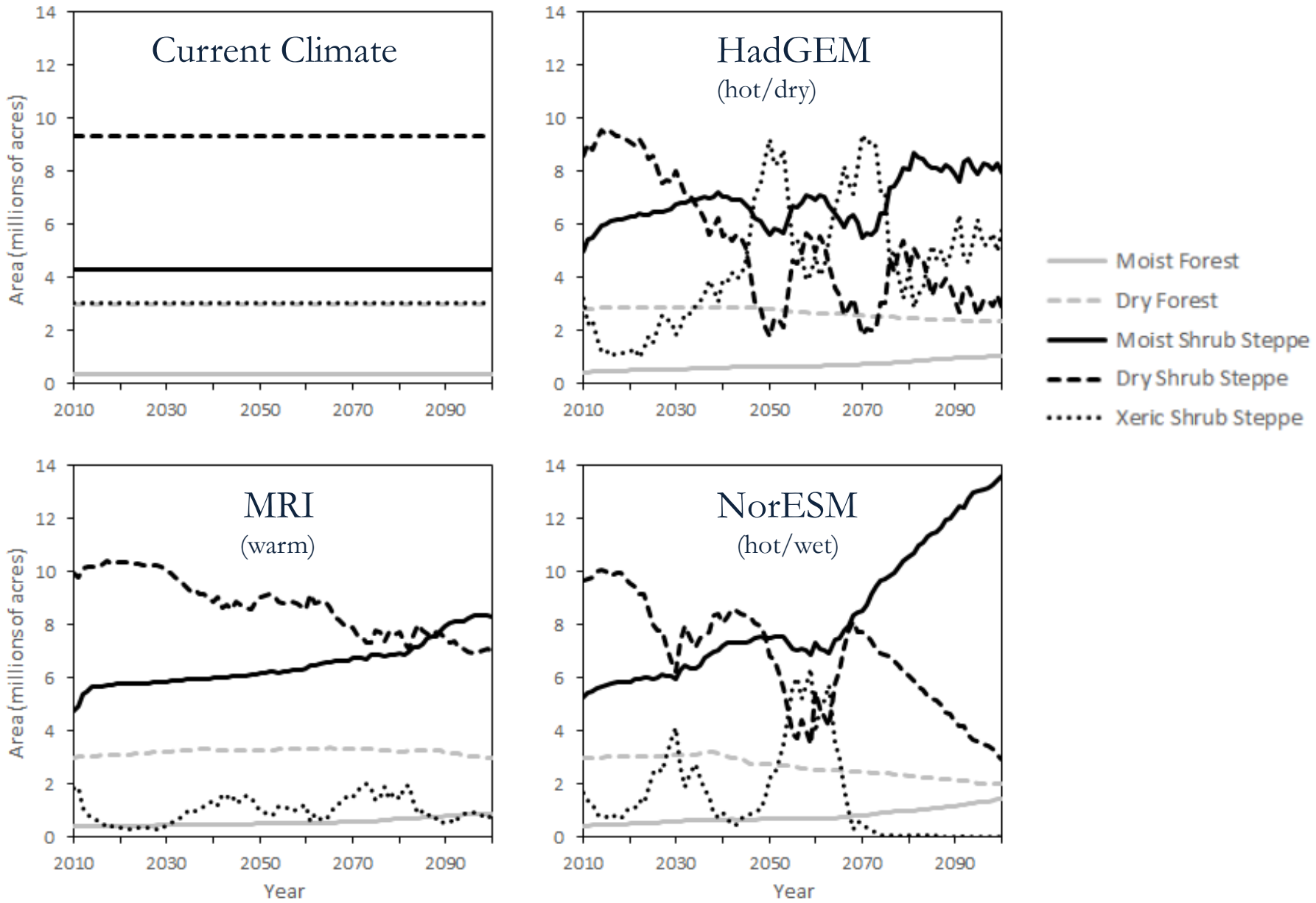




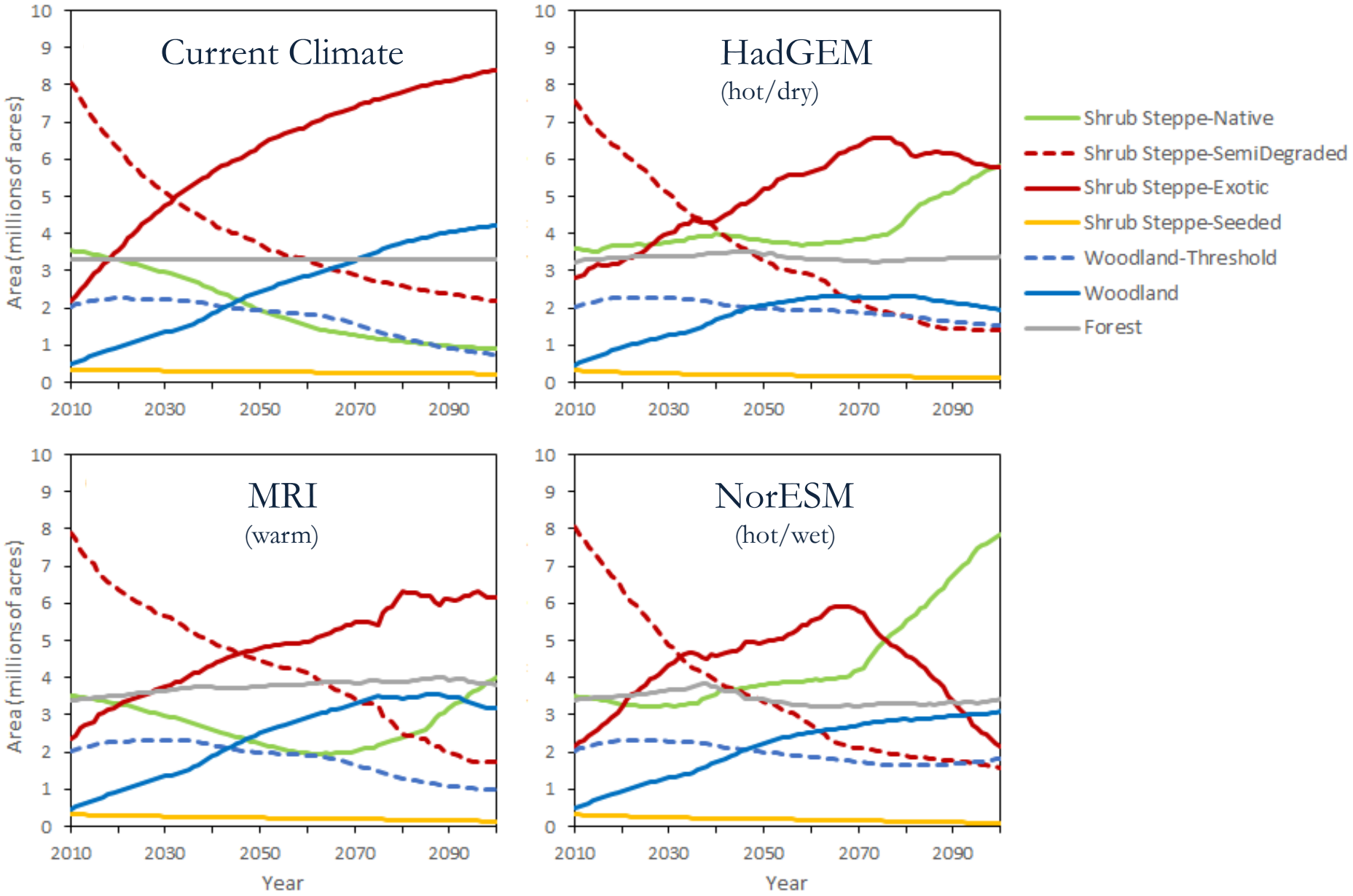
- 3 Global circulation models
  - HadGEM (hot/dry)
  - NorESM (hot/wet)
  - MRI (warm)
- Higher temperatures in all seasons
- Similar or higher annual precipitation

- No Management
- Current Management
  - Current treatments specific to ownership type
- Restoration Management
  - Alternative scenario to restore sage-grouse habitat

Potential Vegetation Types

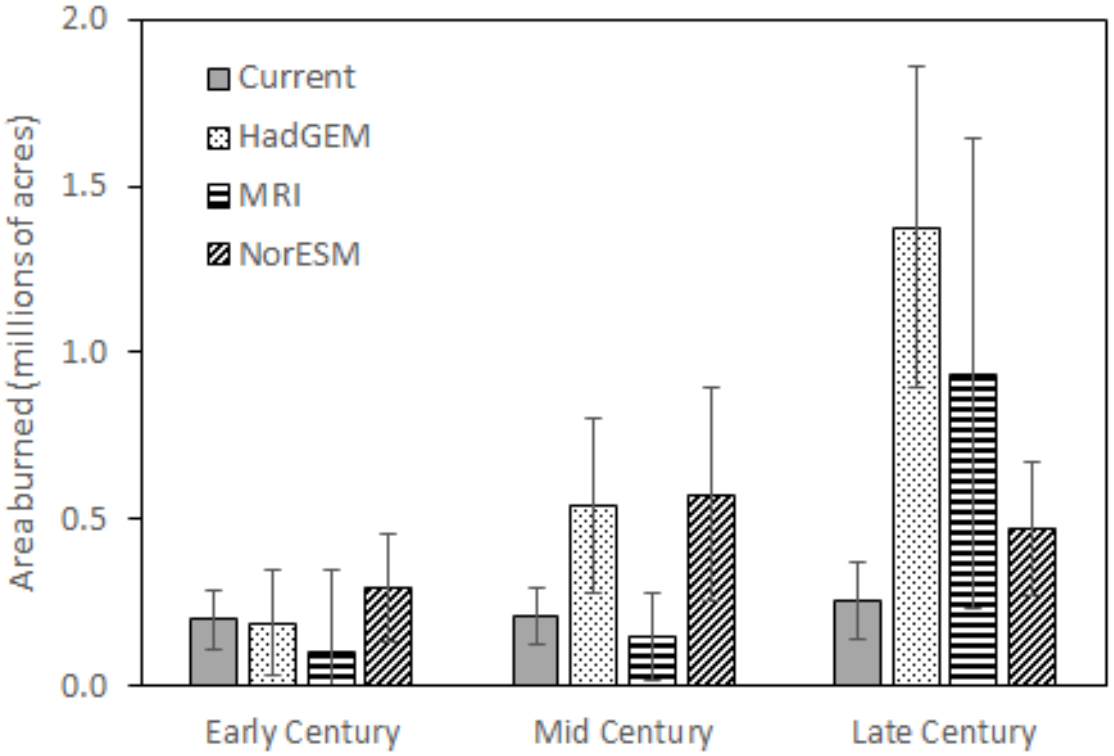


Vegetation Composition



Wildfire

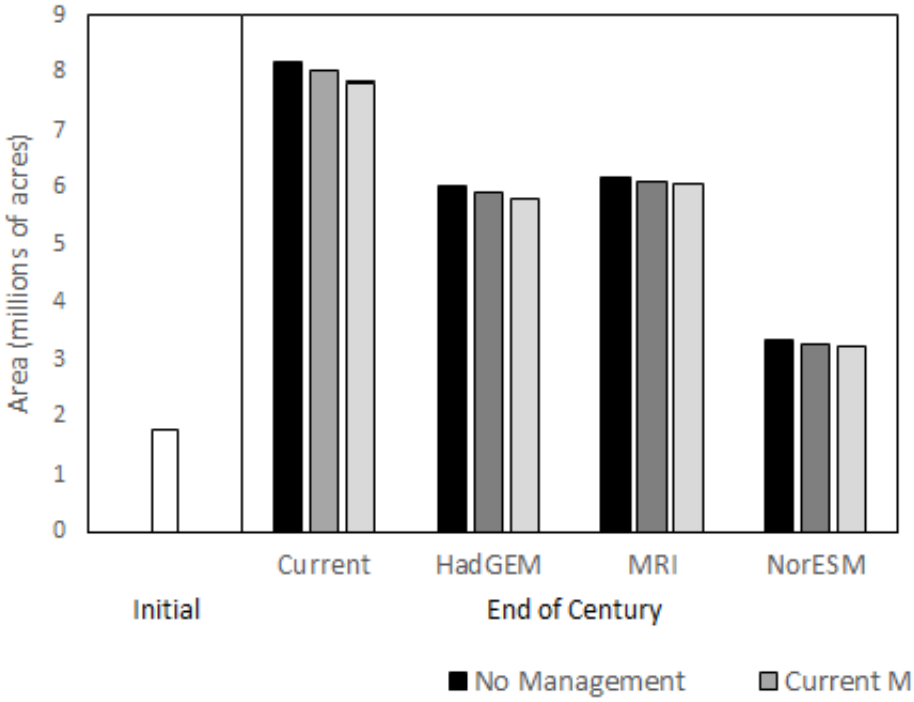
2-4 fold increase in wildfire with climate change

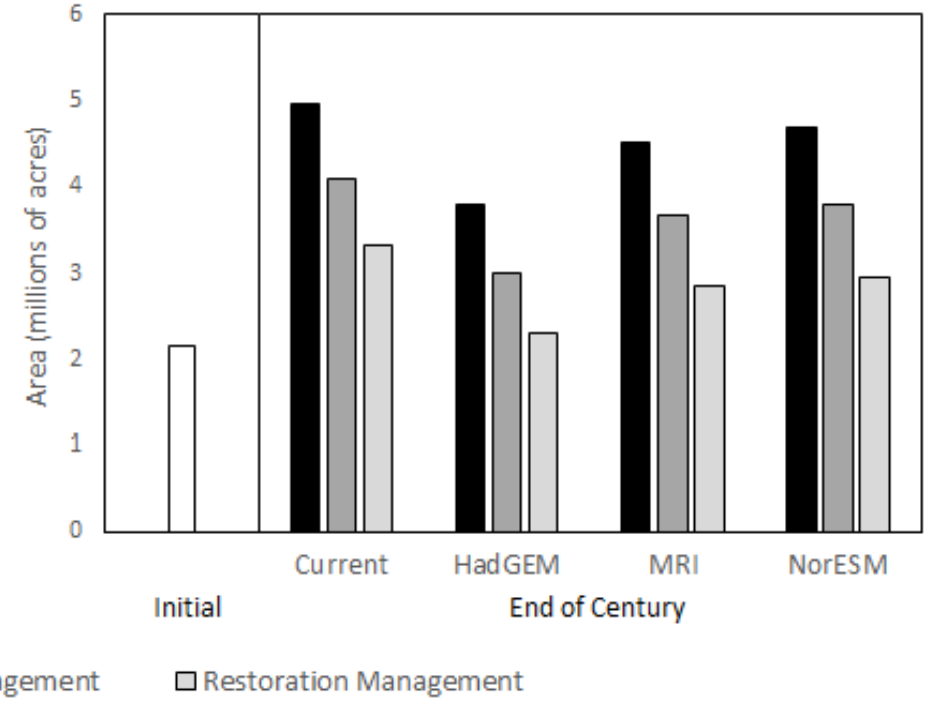


Exotic Grass and Juniper Invasion

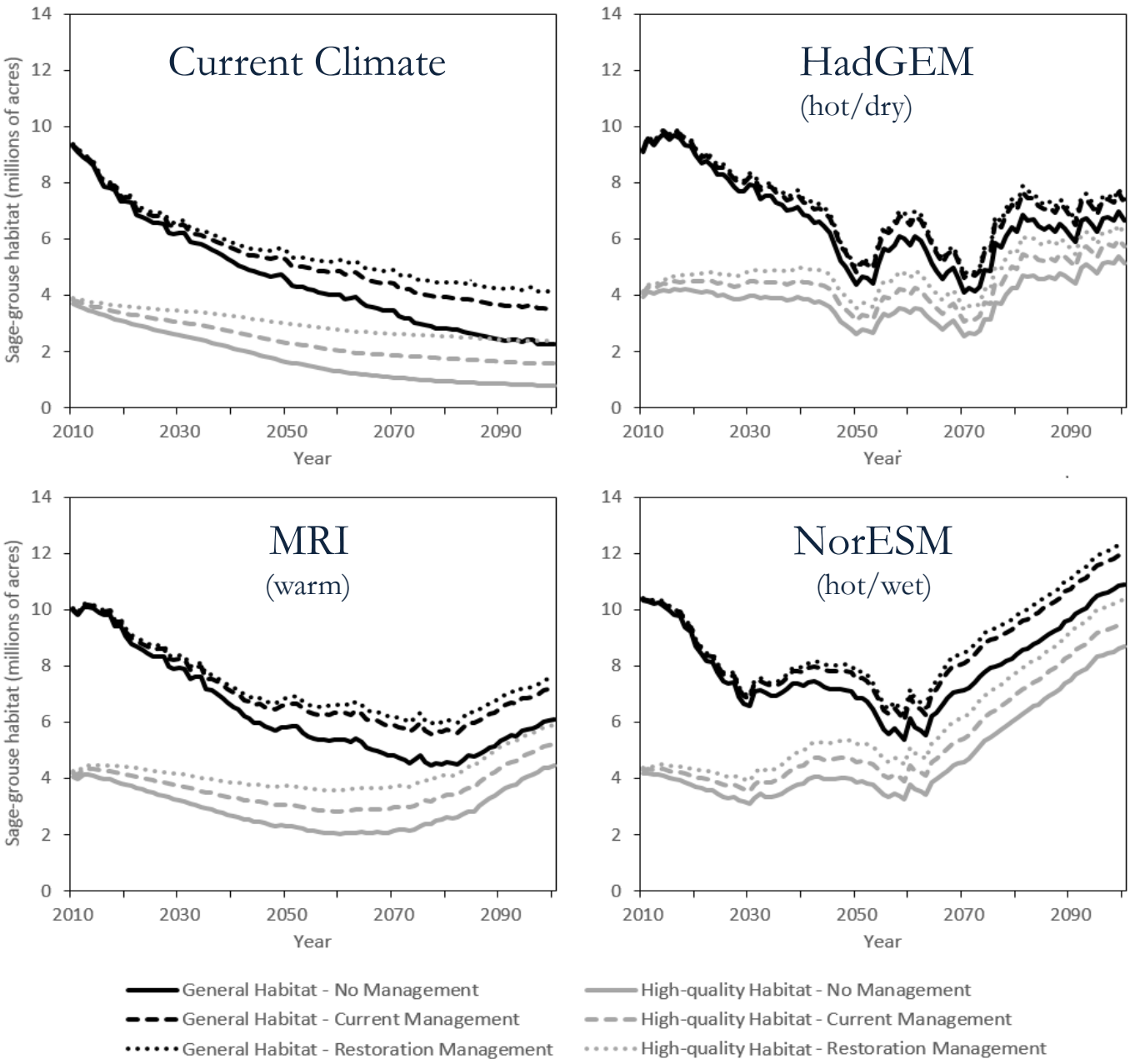
Exotic Grass

Juniper Phases I, II, III





Sage-Grouse Habitat



Conclusions

- Climate change is likely to cause expansion of moist shrub steppe and increases in wildfire
- Current landscape composition presents a high risk for expansion of exotic grasses and juniper
- Climate change is projected to reduce exotic grass and juniper relative to current climate
- Management was effective in controlling juniper but not exotic grass
- Sage-grouse habitat declined in the short term, but rebounded late in the century under some climate change scenarios

Creutzburg, M.K., Grossmann, E.B. Conklin, D. 2015. Climate change and land management impact rangeland condition and sage-grouse habitat in southeastern Oregon. AIMS Environmental Science 2: 203-236.

Summary:
State-and-Transition Simulation Models

- Useful and flexible tool for conceptualizing vegetation dynamics and projecting future conditions
- Used widely to inform management of ecosystems
- Useful for a wide variety of ecosystems
- Can be used to assess impacts of climate change
- Allow incorporation of data from multiple models and other sources

Thank You!

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