National Aeronautics and Space Administration

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Applied Remote Sensing Training

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Introduction to Remote Sensing for Scenario-Based Ecoforecasting

Week 4: Overview of Species Distribution and State-And-Transition Simulation Modeling

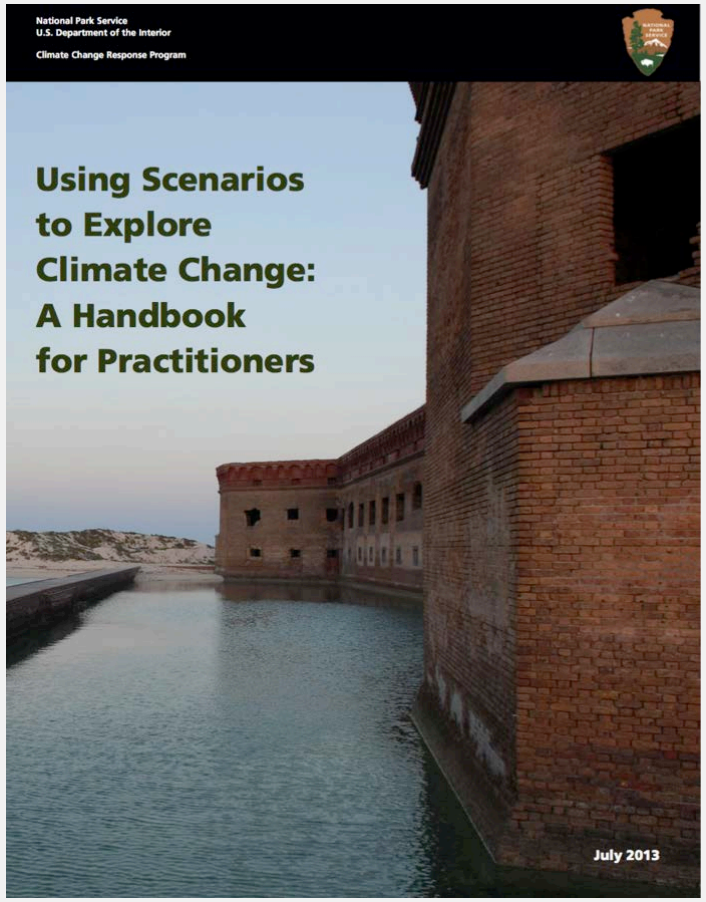
Catherine Jarnevich, Research Ecologist: USGS, Fort Collins Science Center

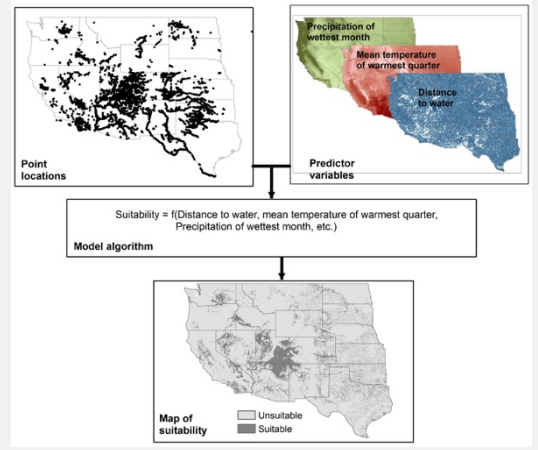
Brian W. Miller, Research Ecologist: USGS, North Central Climate Science Center

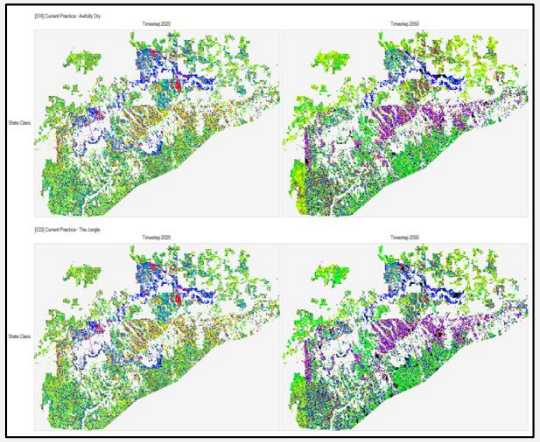
USGS science for a changing world

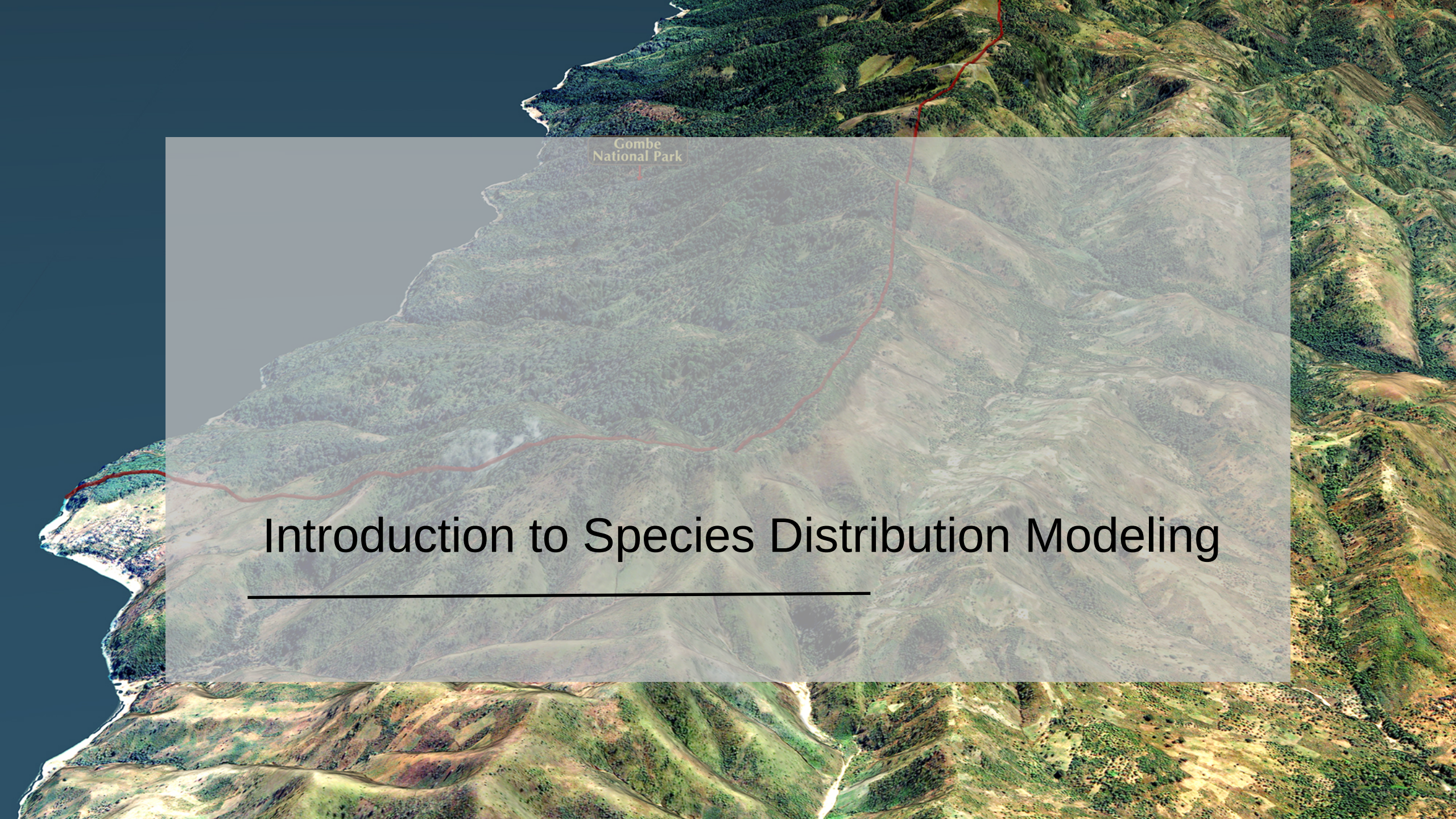
Overview of Species Distribution & State-and-Transition Simulation Modeling

- Qualitative scenario planning has proven useful in a variety of contexts
- Quantitative information often desired or needed
- Quantitative methods include:
  - Species distribution modeling
  - Simulation modeling







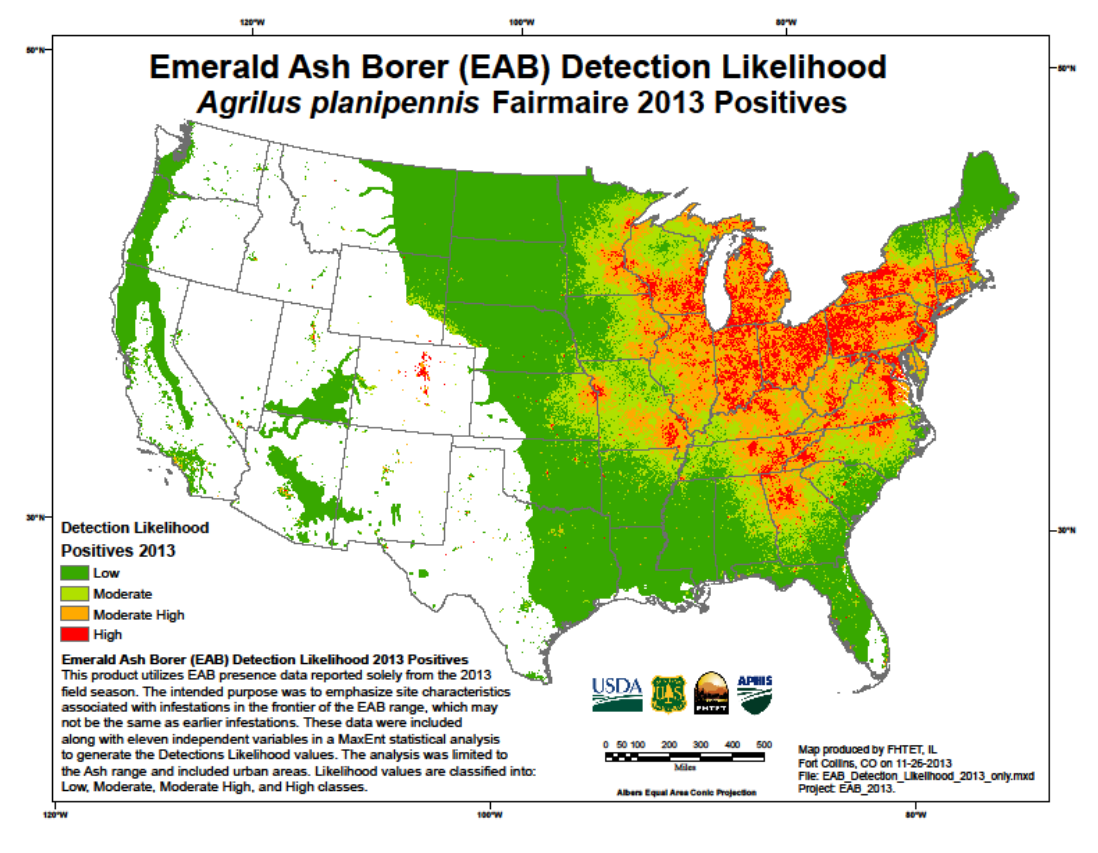


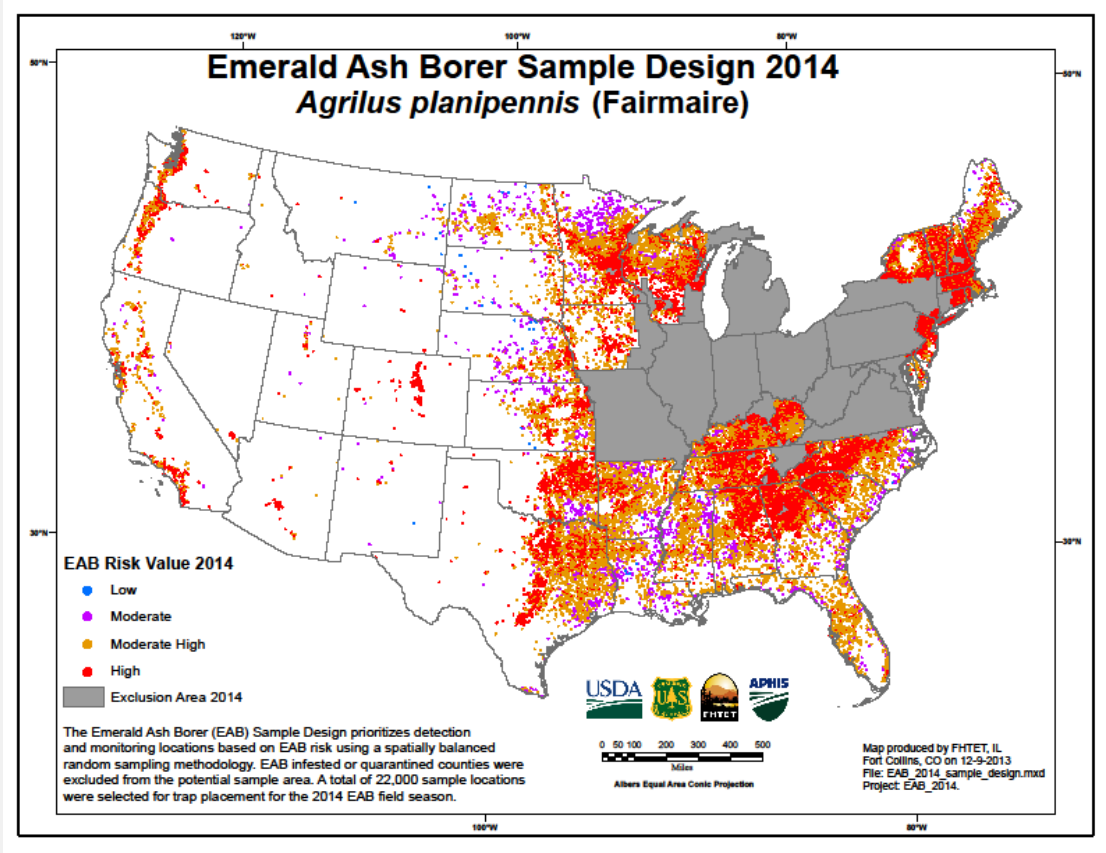
Introduction to Species Distribution Modeling

Overview of Species Distribution & State-and-Transition Simulation Modeling

Introduction

Monitoring Strategies



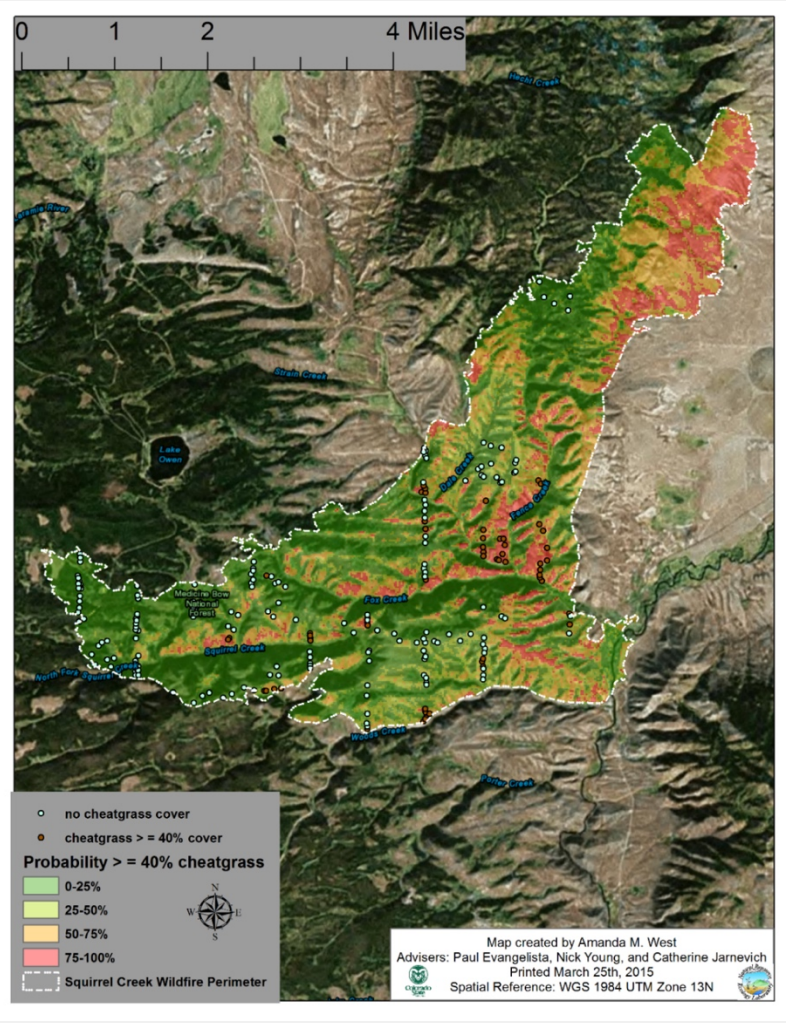


Overview of Species Distribution & State-and-Transition Simulation Modeling

Introduction

- Invasive species control

West et al. 2017, International Journal of Applied Earth Observation and Geoinformation

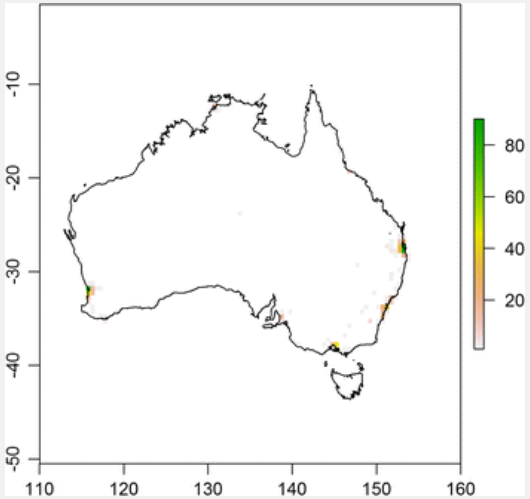


Overview of Species Distribution & State-and-Transition Simulation Modeling

Introduction

- Risk assessment

Predicted incursion events



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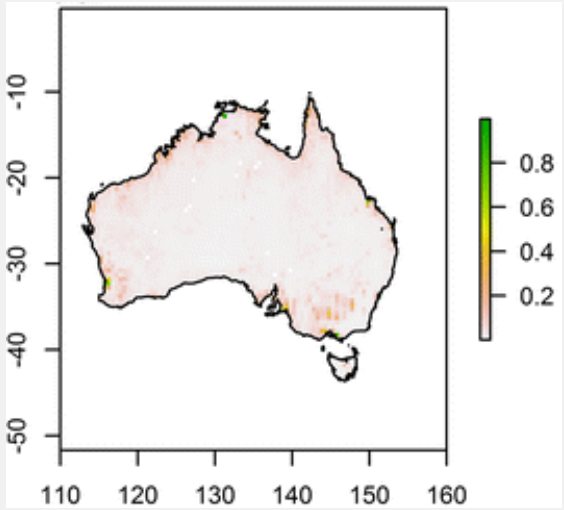
Predicted habitat suitability



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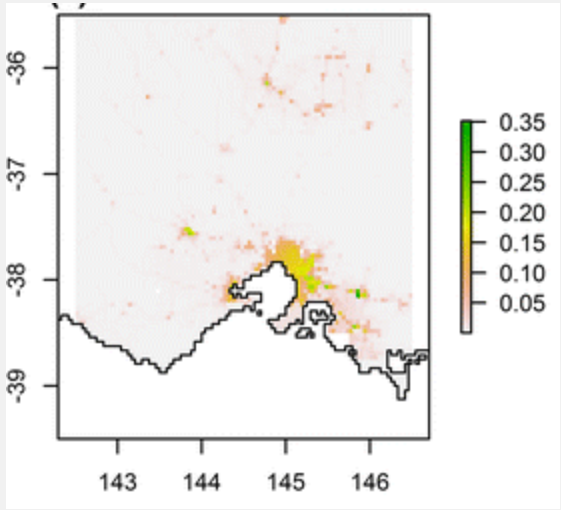
Potential establishment area



Vall-llosera et al. 2017, Biological invasions

Species Distribution Models

Overview of Species Distribution & State-and-Transition Simulation Modeling

Species Distribution Models

Numerical relationships with the environment define where a species may be found

Do:

identify areas with environmental conditions similar to where a species occurs

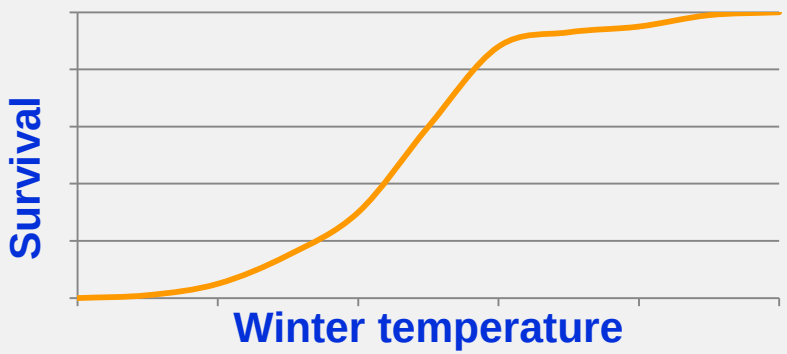
Do not:

necessarily identify where a species actually is

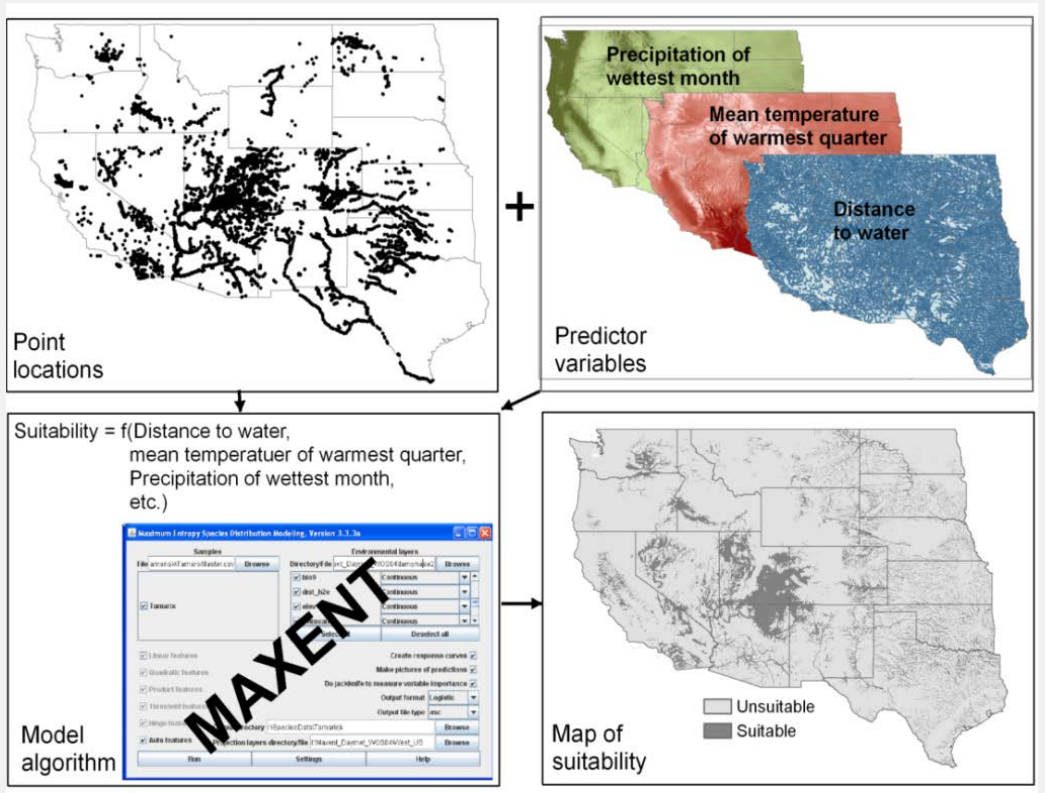
Overview of Species Distribution & State-and-Transition Simulation Modeling

Species Distribution Models

- Process – mechanism; physiological constraints



- Correlation – pattern; based on current locations



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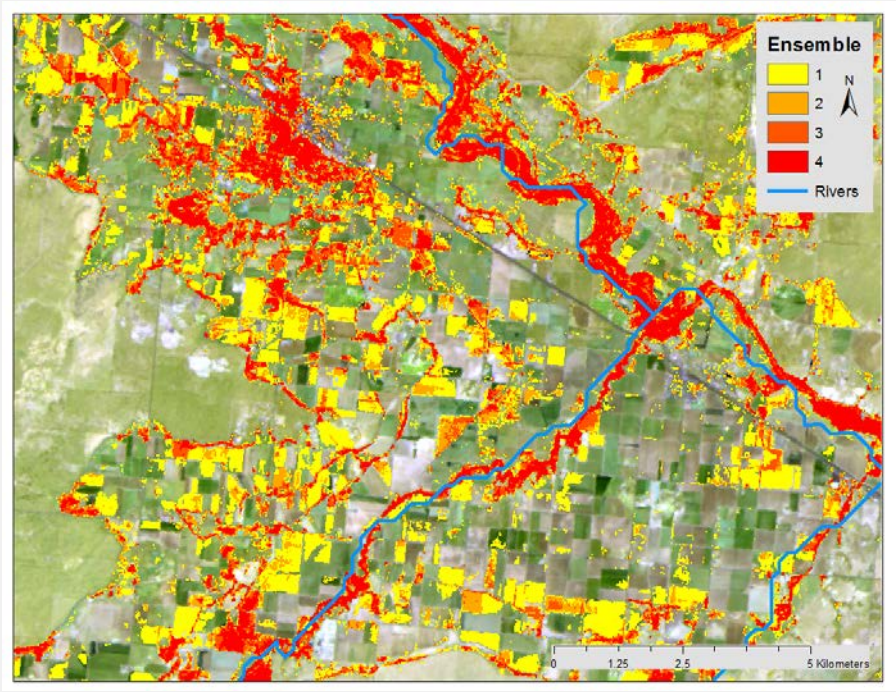
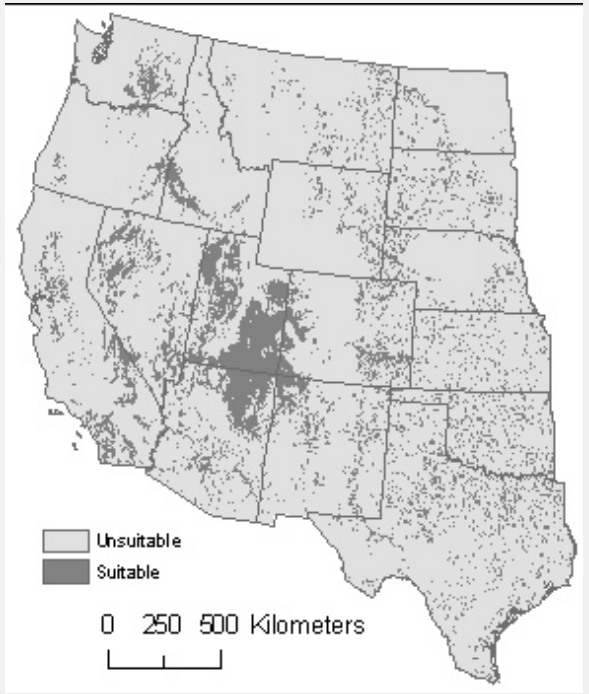
Species Distribution Models

- Where is it now?
  – mapping



West et al. 2016, JoVE

- Where might it be?
  – potential



Jarnevich et al. 2011, Western North American Naturalist

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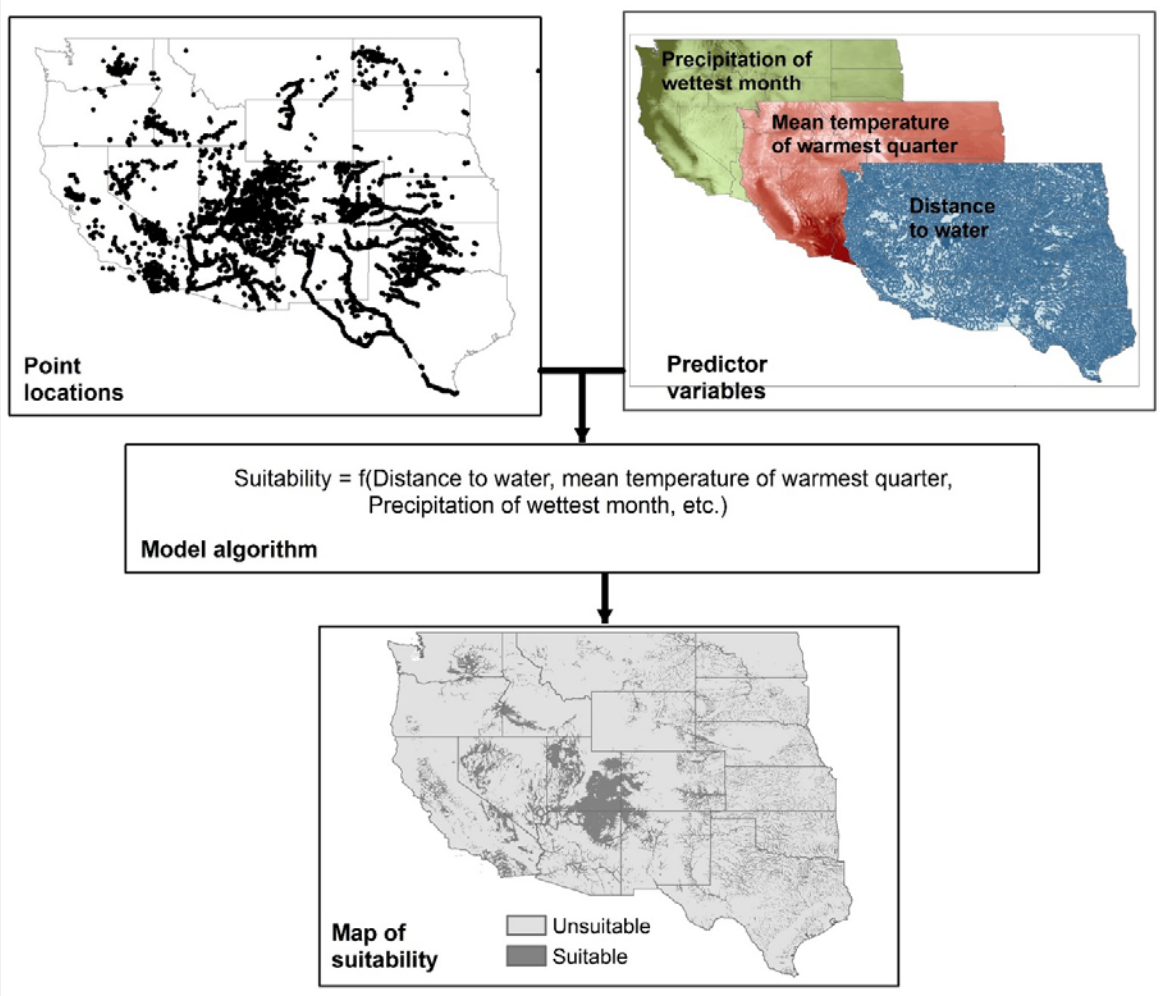
Species Distribution Models



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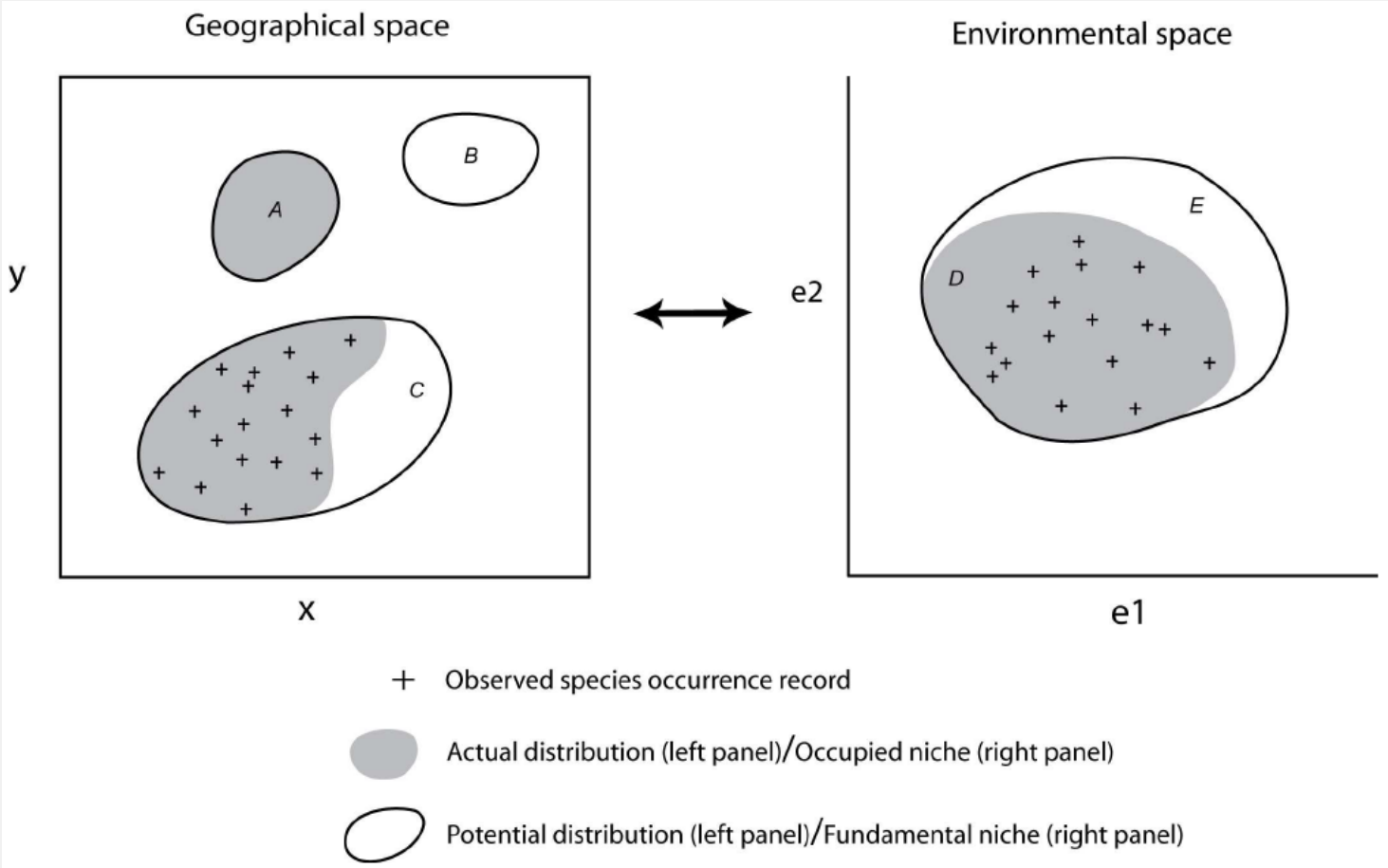
Species Distribution Models



Pearson, R.G. 2007. Species' Distribution Modeling for Conservation Educators and Practitioners. Synthesis. American Museum of Natural History. Available at http://ncep.amnh.org.

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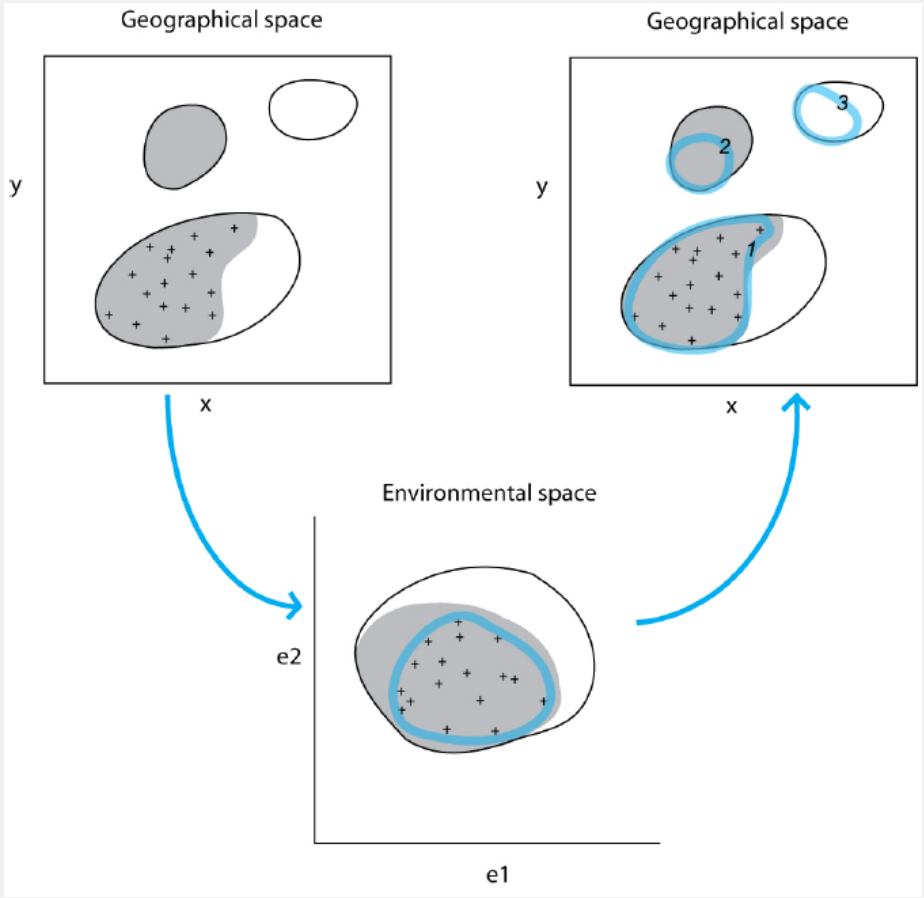
Species Distribution Models



+ Observed species occurrence record

Actual distribution (upper panels)/Occupied niche (lower panel)

Potential distribution (upper panels)/Fundamental niche (lower panel)

Species distribution model fitted to observed occurrence records

Pearson, R.G. 2007. Species' Distribution Modeling for Conservation Educators and Practitioners. Synthesis. American Museum of Natural History. Available at http://ncep.amnh.org.

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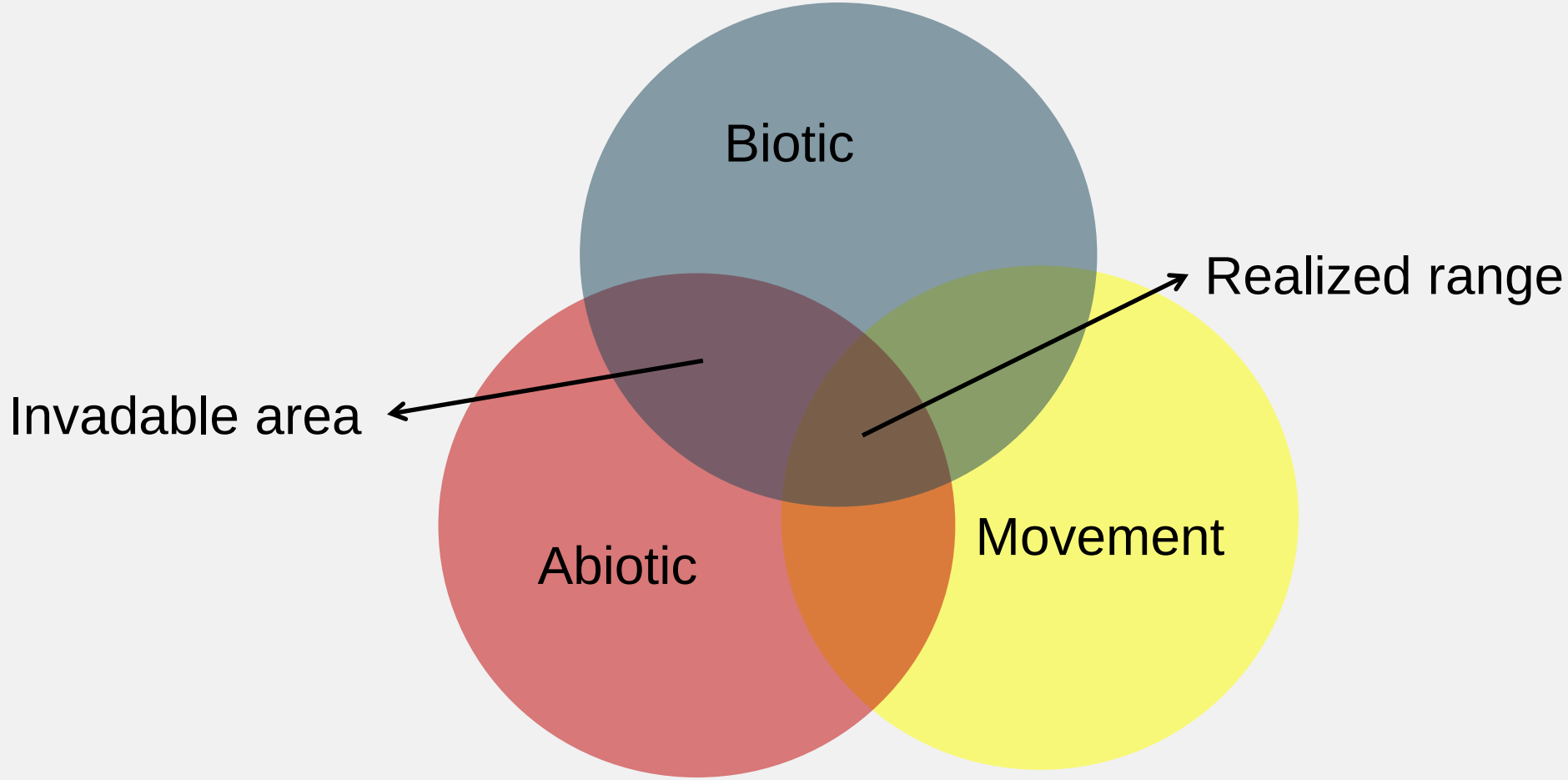
Species Distribution Models



Soberon and Peterson 2005, Biodiversity Informatics

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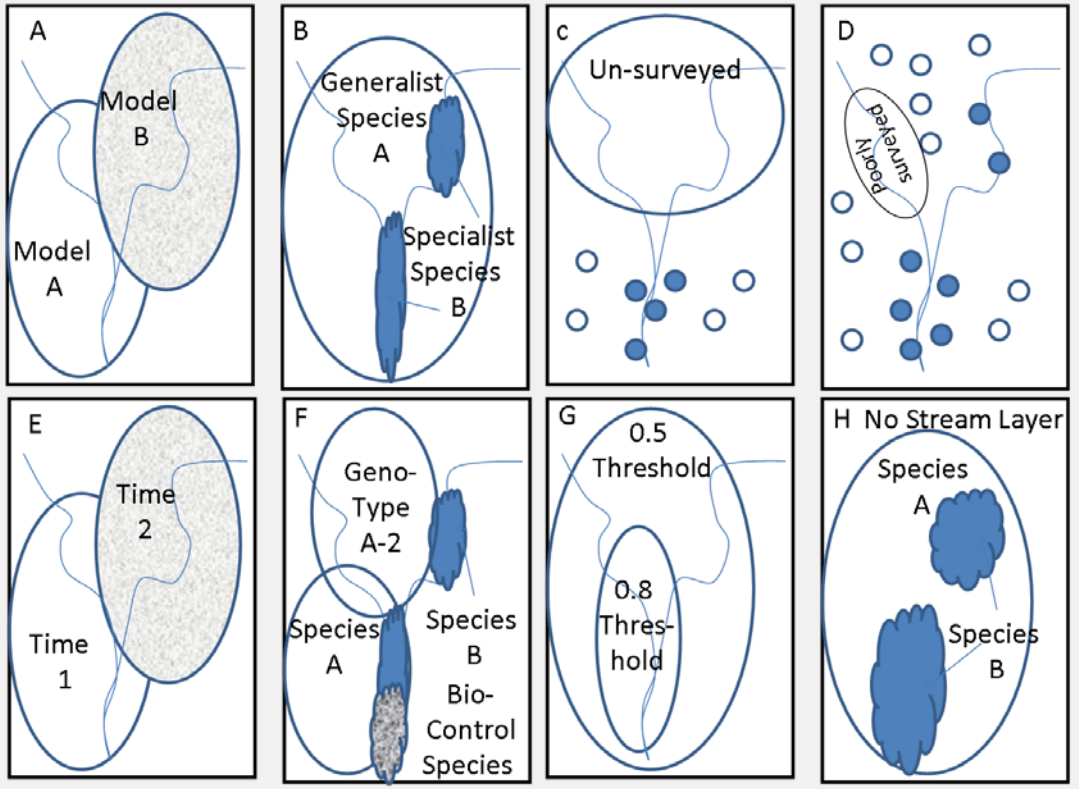
Species Distribution Models

- Assessment

- Caveats



Jarnevich et al. 2015, Ecological informatics

VisTrails: SAHM software

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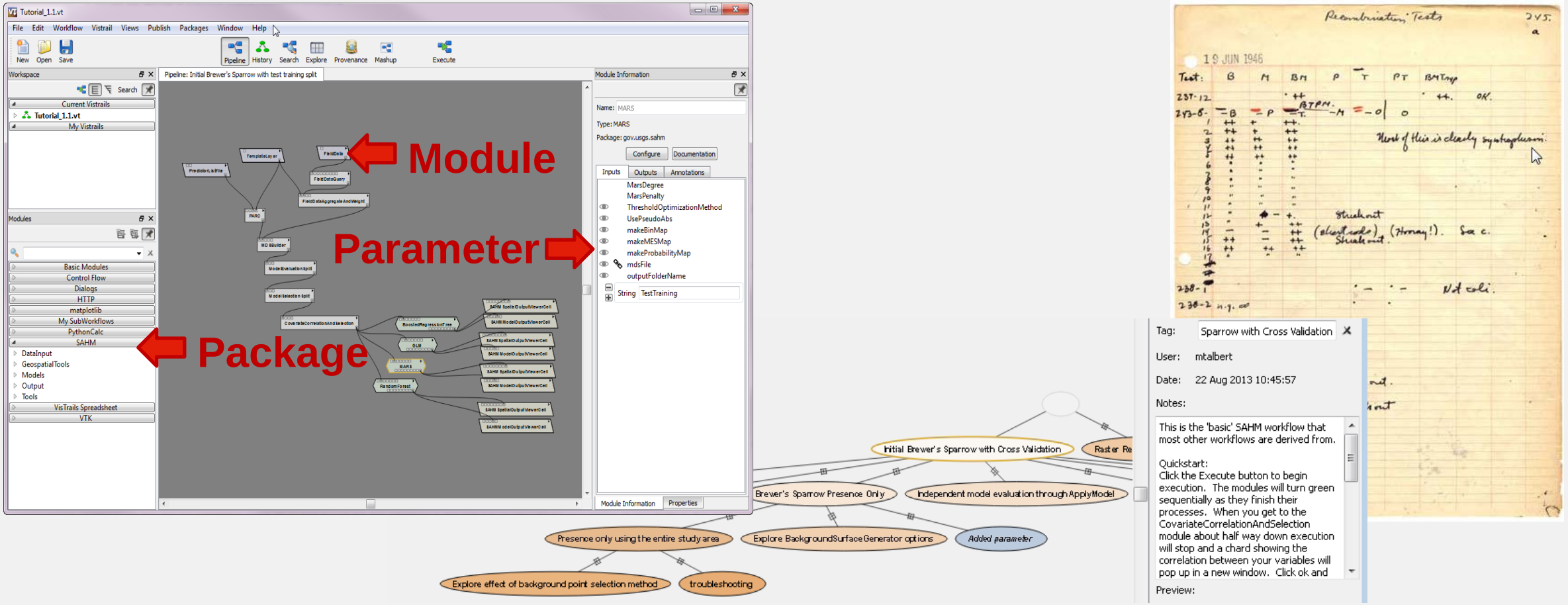
VisTrails: SAHM software



Morisette et al. 2013, Ecography

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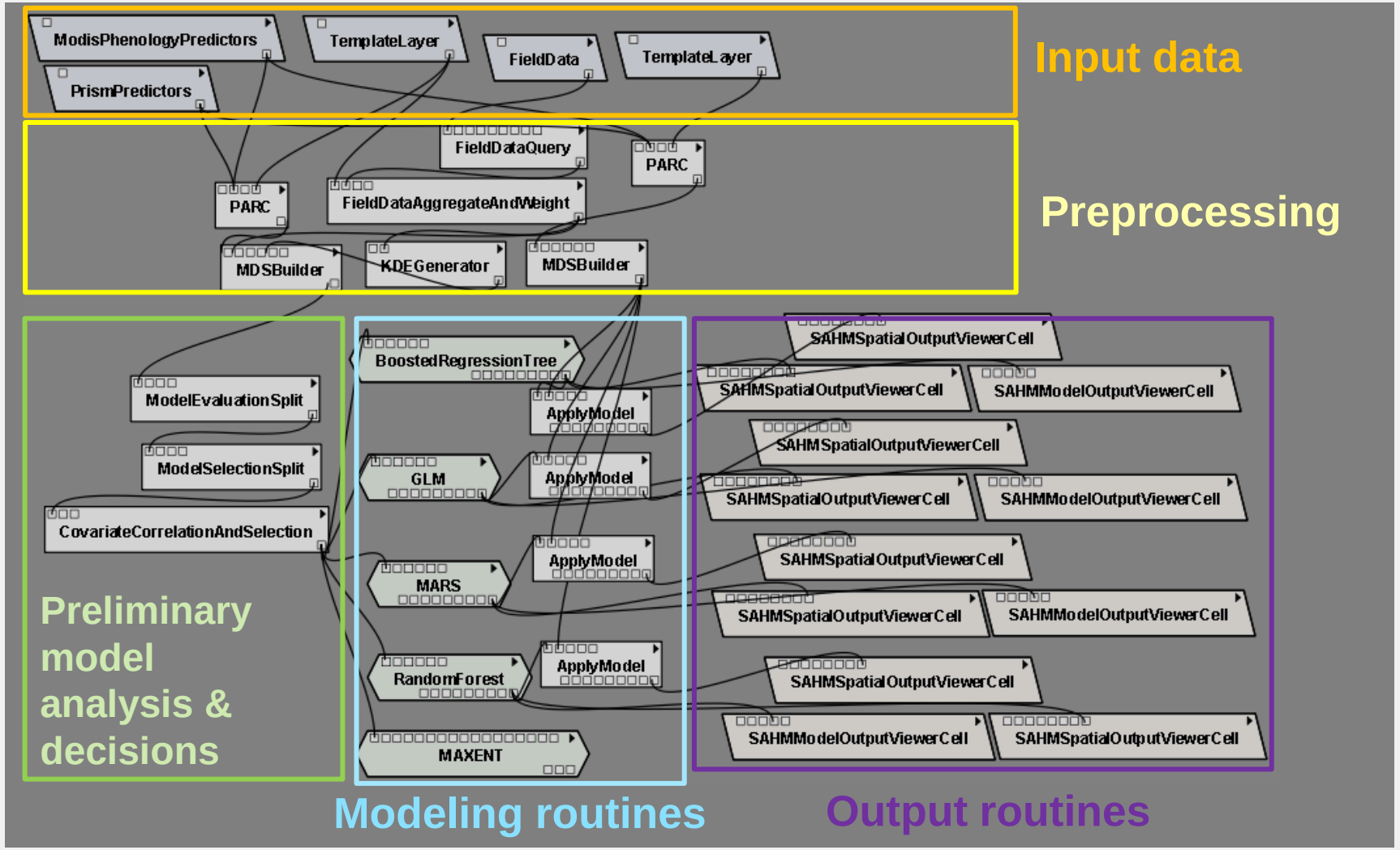
VisTrails: SAHM software

VisTrails: SAHM standard workflow



Morisette et al. 2013, Ecography

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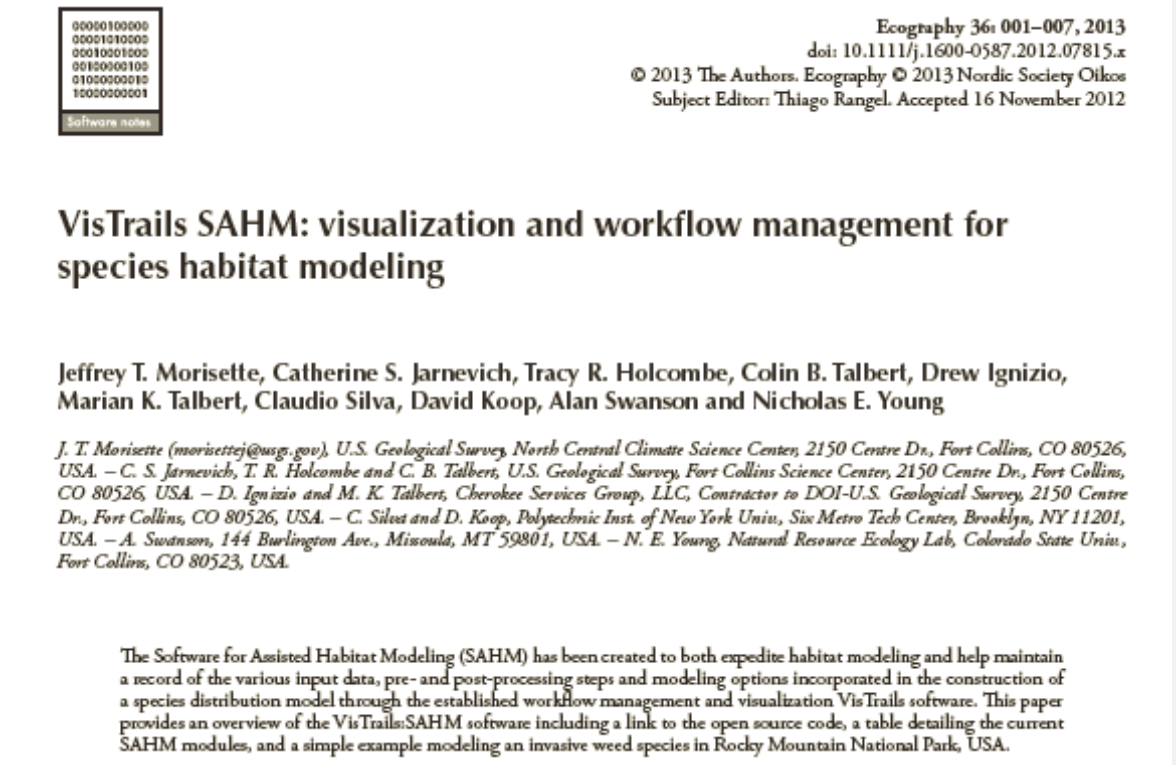
VisTrails: SAHM software

- Freely available software
- Google group: https://groups.google.com/forum/?fromgroups=#!forum/vistrails-sahm
- Ecography paper
- User's guide and tutorial
- Training materials https://my.usgs.gov/catalog/RAM/SAHM



Ecography 36: 001–007, 2013
doi: 10.1111/j.1600-0587.2012.07815.x

Subject Editor: Thiago Rangel. Accepted 16 November 2012

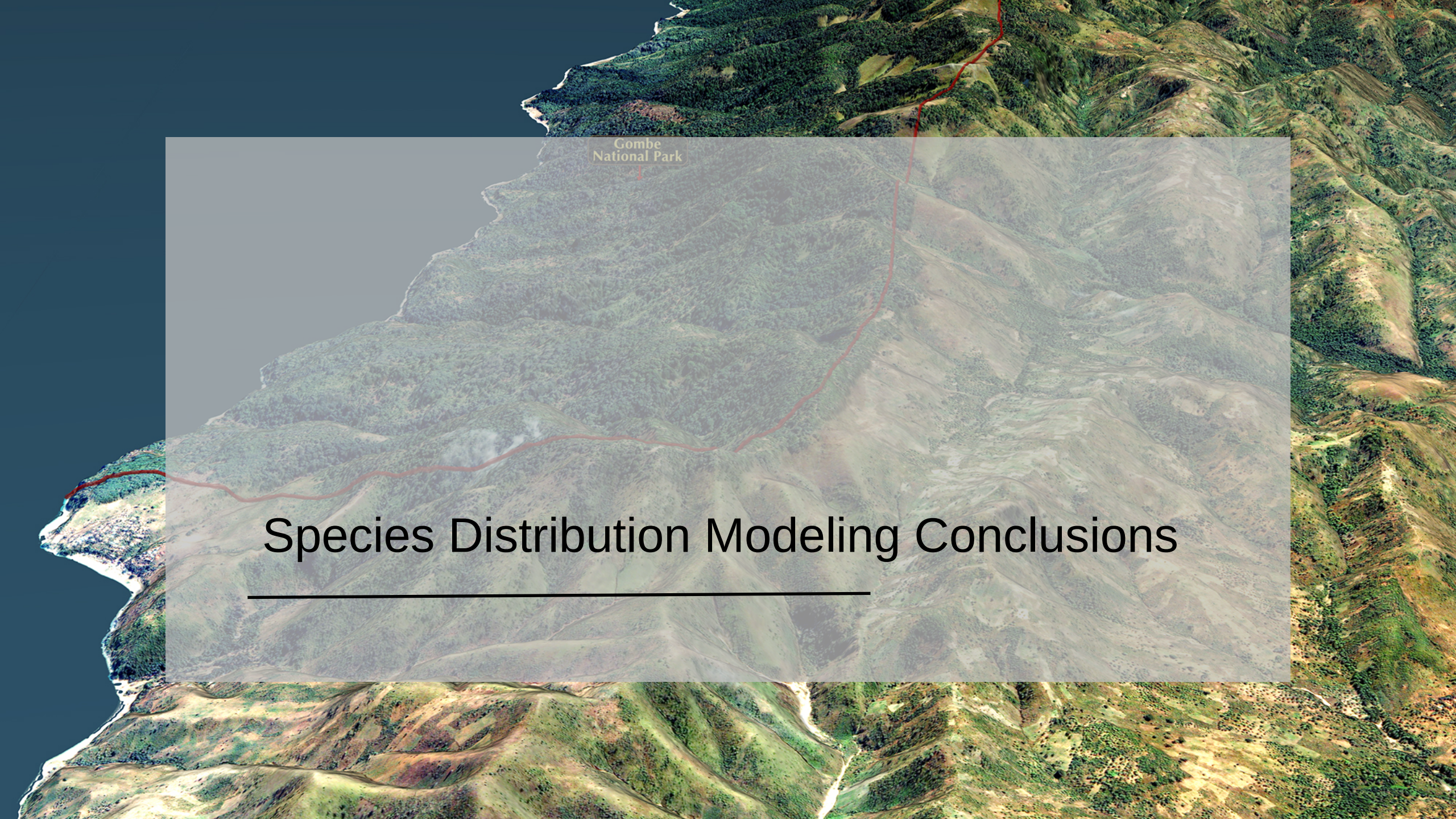
Software notes

VisTrails SAHM: visualization and workflow management for species habitat modeling

Jeffrey T. Morisette, Catherine S. Jarnevich, Tracy R. Holcombe, Colin B. Talbert, Drew Ignizio, Marian K. Talbert, Claudio Silva, David Koop, Alan Swanson and Nicholas E. Young

J. T. Morisette (morisettej@usgs.gov), U.S. Geological Survey, North Central Climate Science Center, 2150 Centre Dr., Fort Collins, CO 80526, USA. – C. S. Jarnevich, T. R. Holcombe and C. B. Talbert, U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Dr., Fort Collins, CO 80526, USA. – D. Ignizio and M. K. Talbert, Cherokee Services Group, LLC, Contractor to DOI-U.S. Geological Survey, 2150 Centre Dr., Fort Collins, CO 80526, USA. – C. Silva and D. Koop, Polytechnic Inst. of New York Univ., Six Metro Tech Center, Brooklyn, NY 11201, USA. – A. Swanson, 144 Burlington Ave., Missoula, MT 59801, USA. – N. E. Young, Natural Resource Ecology Lab, Colorado State Univ., Fort Collins, CO 80523, USA.

The Software for Assisted Habitat Modeling (SAHM) has been created to both expedite habitat modeling and help maintain a record of the various input data, pre- and post-processing steps and modeling options incorporated in the construction of a species distribution model through the established workflow management and visualization VisTrails software. This paper provides an overview of the VisTrails:SAHM software including a link to the open source code, a table detailing the current SAHM modules, and a simple example modeling an invasive weed species in Rocky Mountain National Park, USA.



Species Distribution Modeling Conclusions

Overview of Species Distribution & State-and-Transition Simulation Modeling

Species distribution modeling conclusions

- No universally correct way!

- Methodology adapted to
  - Ecological and biogeographical situation
  - Meet study goals
  - Available data

- VisTrails: SAHM is one software option

Simulation Models

Overview of Species Distribution & State-and-Transition Simulation Modeling

Species Distribution Modeling

- Correlative models of abiotic variables & species occurrence
- Common tool for estimating species response to climate
- *Does not project species distributions, models project suitable climates*
- *Does not account for disturbances, competition, or management*

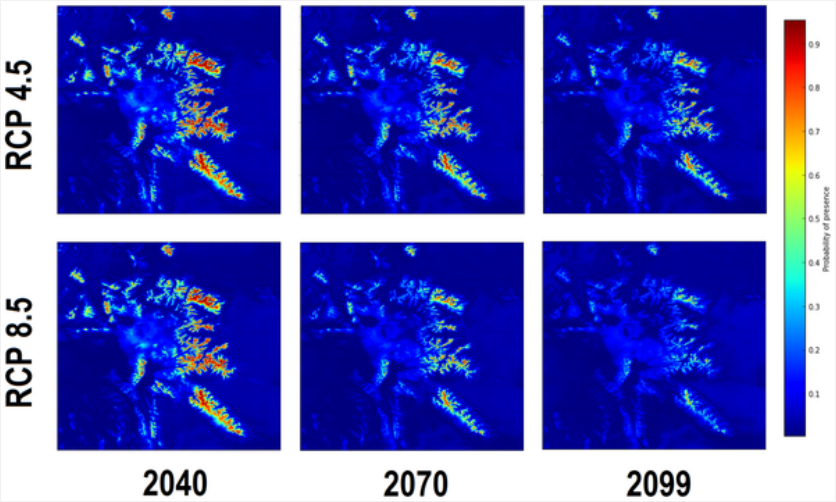
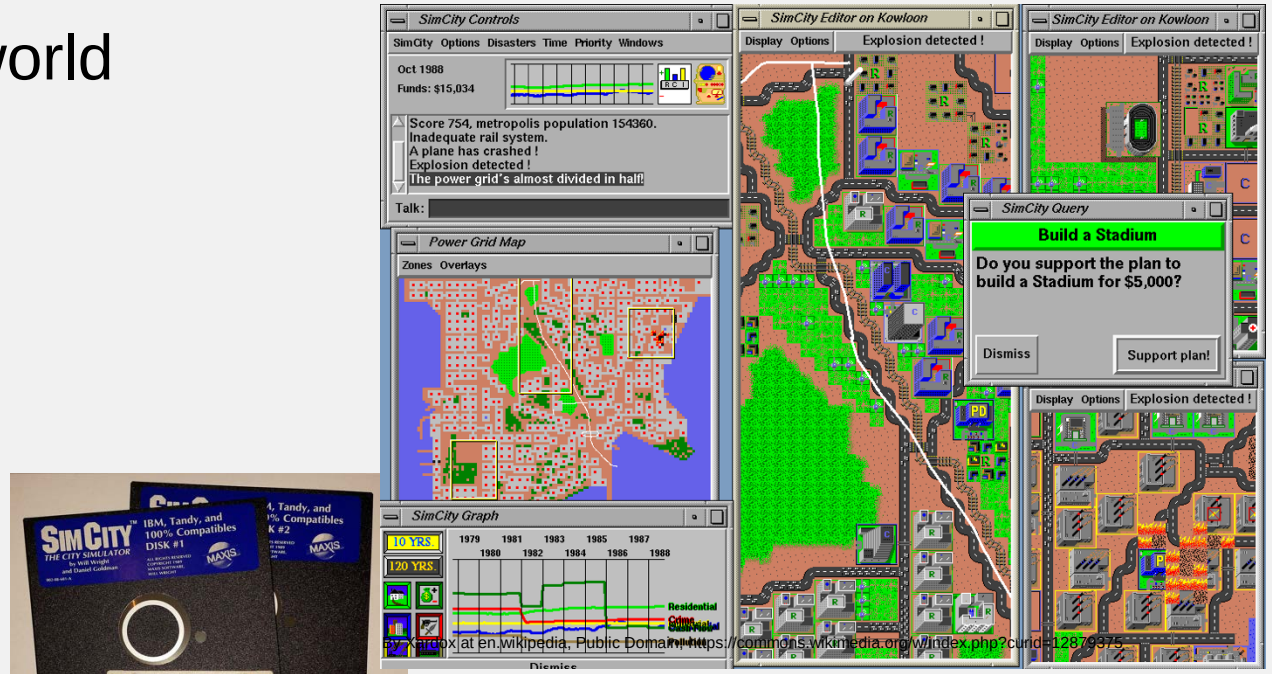


Image: Chang, T., Hansen, A.J. and, N., 2014. Patterns and variability of projected bioclimatic habitat for Pinus albicaulis in the Greater Yellowstone Area. PloS one, 9(11), p.e111669.

Overview of Species Distribution & State-and-Transition Simulation Modeling

Simulation Models

- Computer-based prototype of real world



By Xardox at en.wikipedia, Public Domain, https://commons.wikimedia.org/w/index.php?curid=12879375

By Will Right, Deniel Goldman, Maxis, GPL, https://commons.wikimedia.org/w/index.php?curid=46842817

Overview of Species Distribution & State-and-Transition Simulation Modeling

Simulation Models

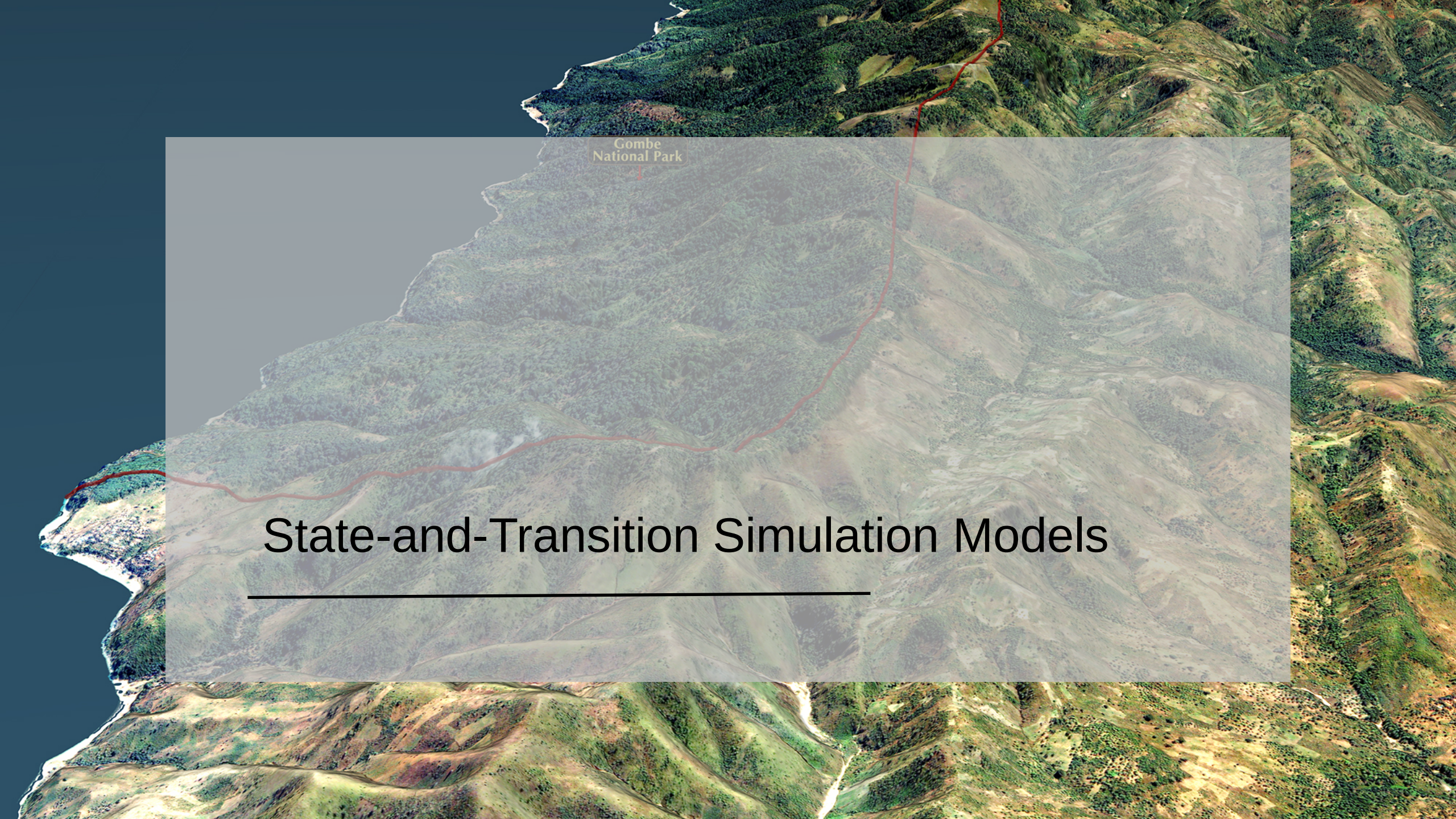
- Computer-based prototype of real world
- Many kinds of simulation models:
  - Climate
  - Population
  - Biogeochemistry
  - Dynamic Global Vegetation Models
  - Agent-Based Models
  - State-and-Transition Simulation Models
  - Etc…

Images: B. W. Miller

Overview of Species Distribution & State-and-Transition Simulation Modeling

Simulation Models

- Why Simulations?
  - Integrate data
  - Identify data gaps and influential uncertainties
  - Reproduce complexity
    - Thresholds, secondary effects, emergence
  - Understand processes
  - Explore “what if…?” scenarios
- What can’t they do?
  - Create scenarios
  - Capture everything
  - Statistical analysis
  - Give you the answer



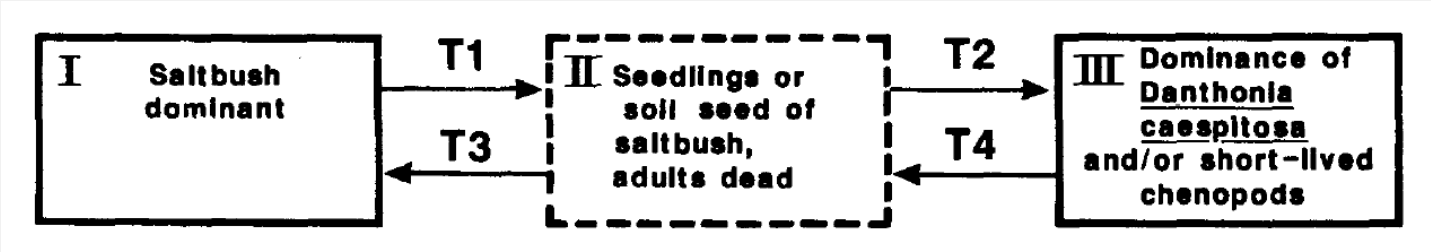
State-and-Transition Simulation Models

Overview of Species Distribution & State-and-Transition Simulation Modeling

State-and-Transition Simulation Models

- **States**: any suite of vegetation communities

- **Transitions**: process (natural or management) that can move vegetation between states



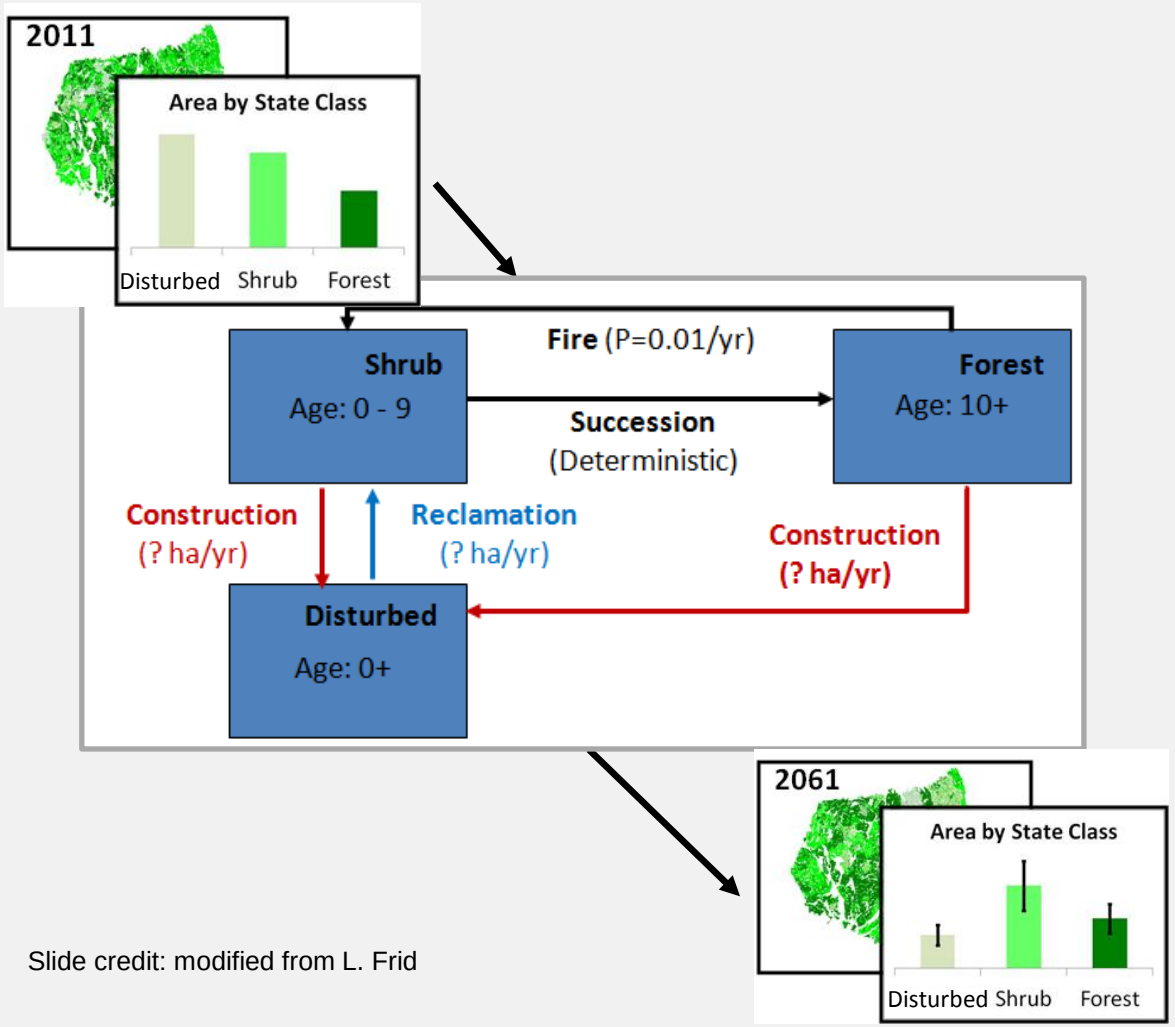
Source: Westoby et al. (1989)

Westoby, M., Walker, B. and Noy-Meir, I., 1989. Opportunistic management for rangelands not at equilibrium. Journal of range management, pp.266-274.

Overview of Species Distribution & State-and-Transition Simulation Modeling

State-and-Transition Simulation Models

- Stochastic simulation models
- Run using software
- Can be spatially explicit
- Model Inputs:
  - Transition probabilities and/or targets
  - Area in each state today
- Model Outputs:
  - Area in each state over time
  - Area transitioned over time
- → Predict vegetation dynamics (w/uncertainty)



Slide credit: modified from L. Frid

Overview of Species Distribution & State-and-Transition Simulation Modeling

State-and-Transition Simulation Models

Image: L. Frid

Daniel, C. J., Frid, L., Sleeter, B. M. and Fortin, M.-J. (2016), State-and-transition simulation models: a framework for forecasting landscape change. Methods Ecol Evol, 7: 1413–1423.

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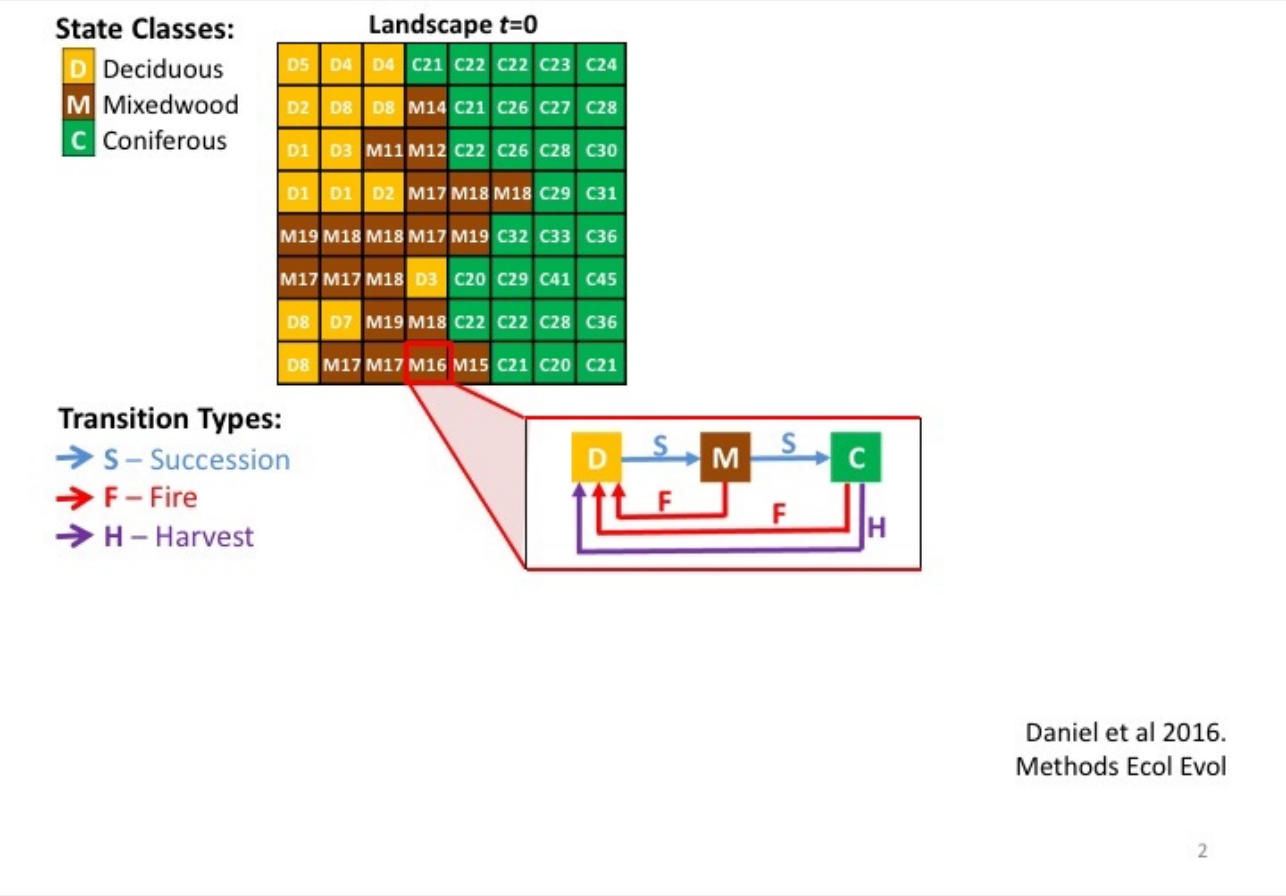
State-and-Transition Simulation Models



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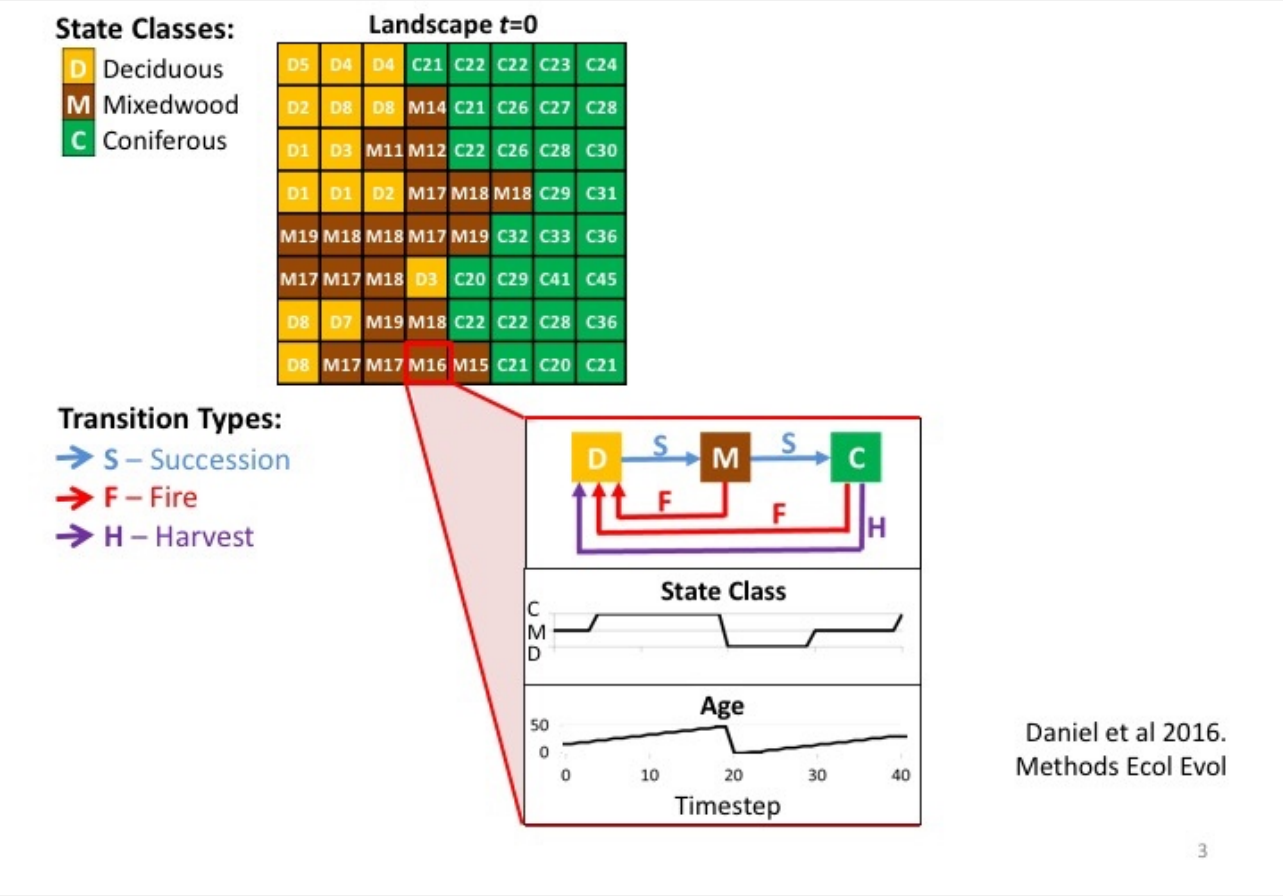
State-and-Transition Simulation Models



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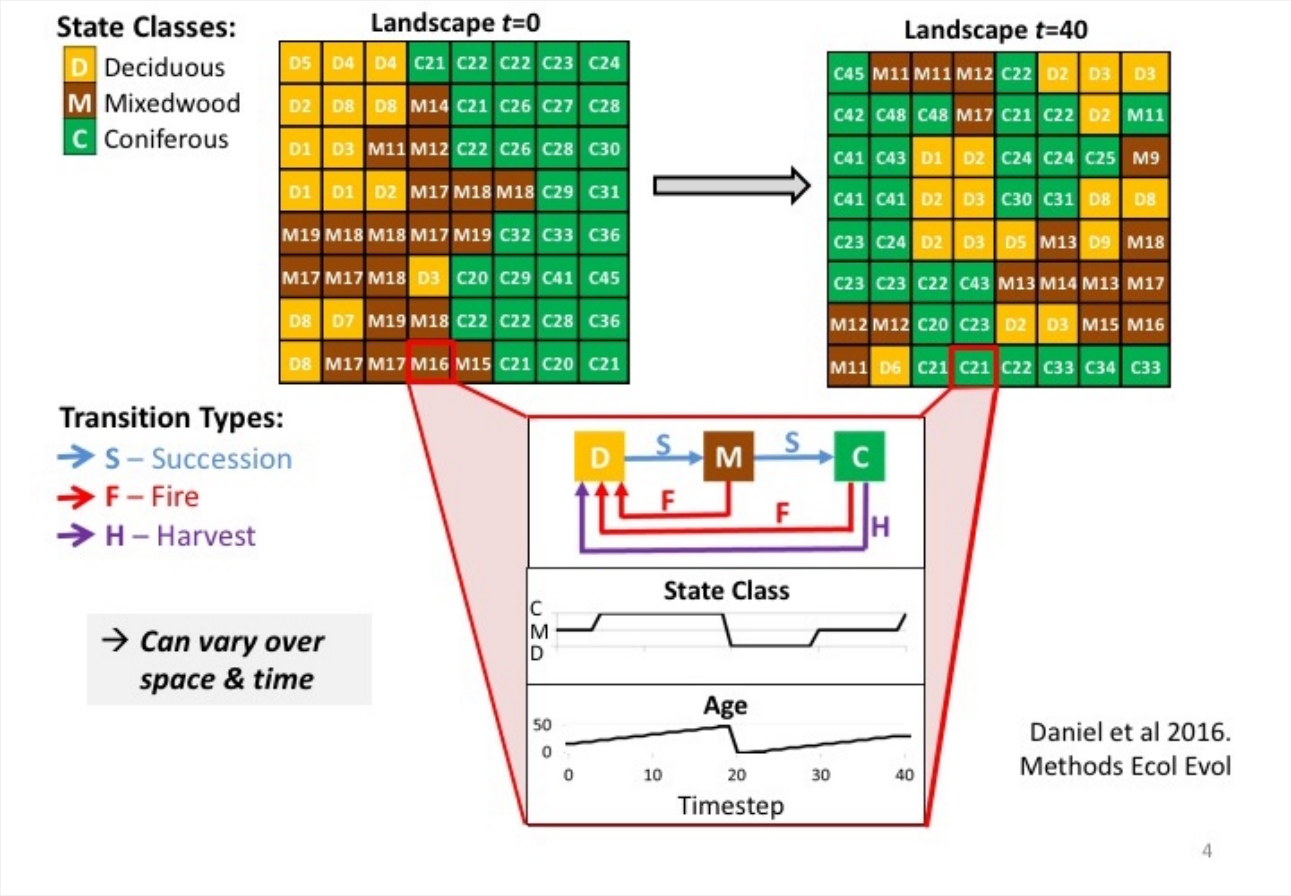
State-and-Transition Simulation Models



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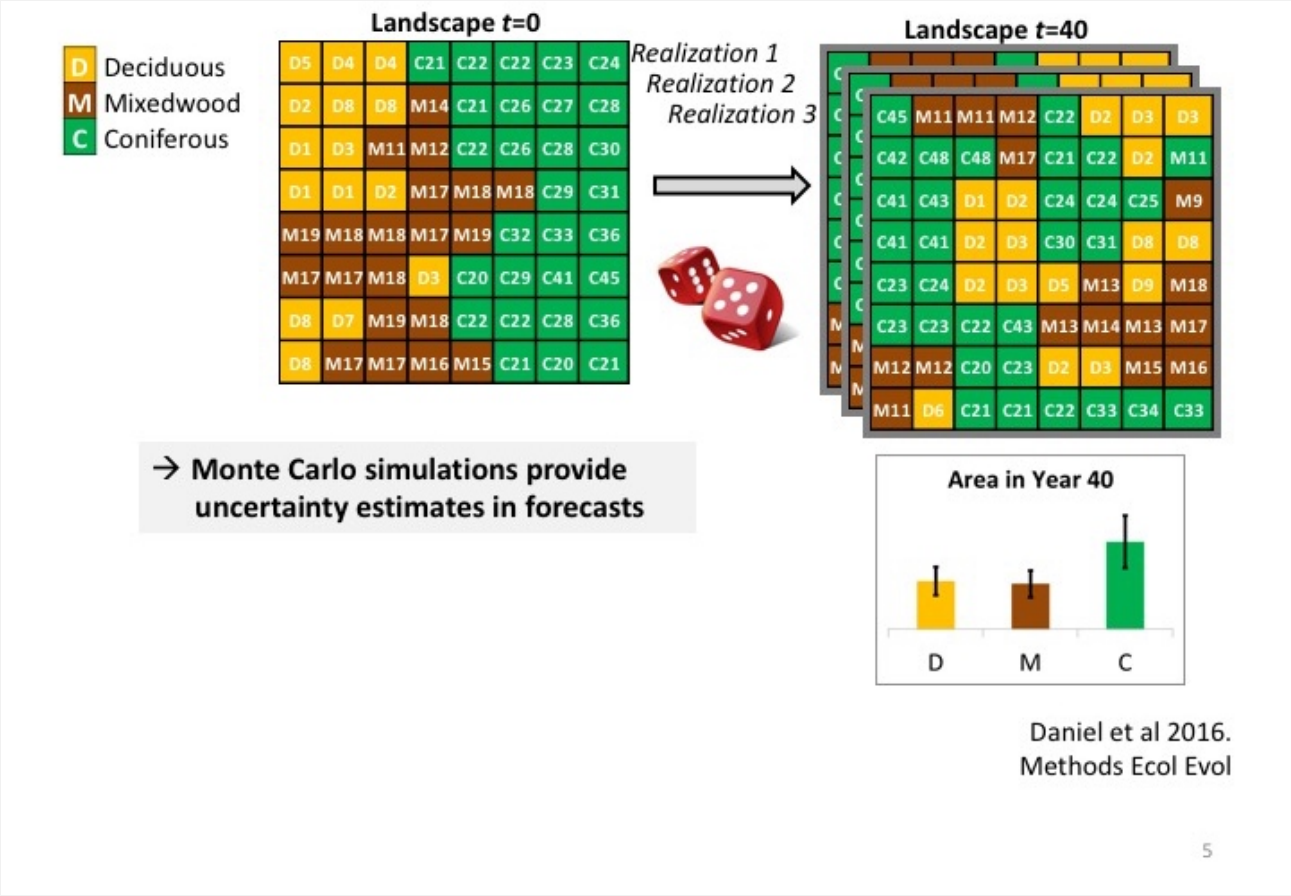
State-and-Transition Simulation Models



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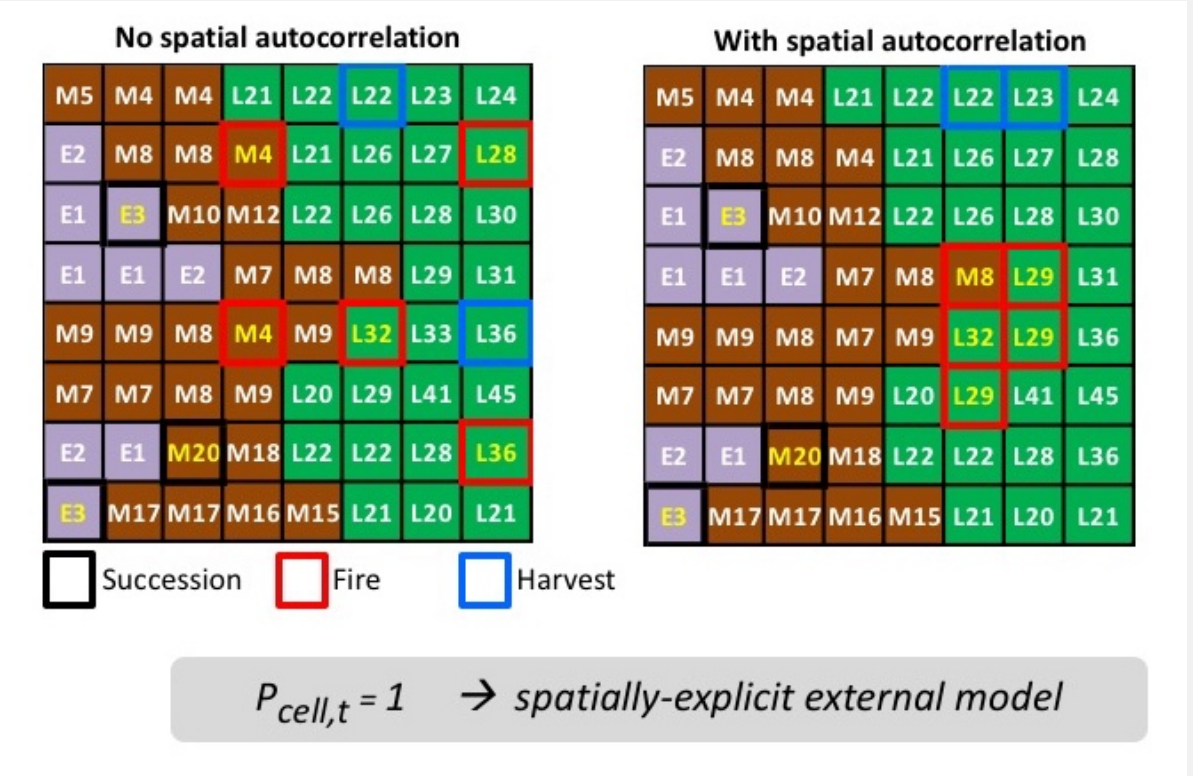
Overview of Species Distribution & State-and-Transition Simulation Modeling

State-and-Transition Simulation Models

- Optional Model Features
  - Spatial autocorrelation (e.g., clustering)



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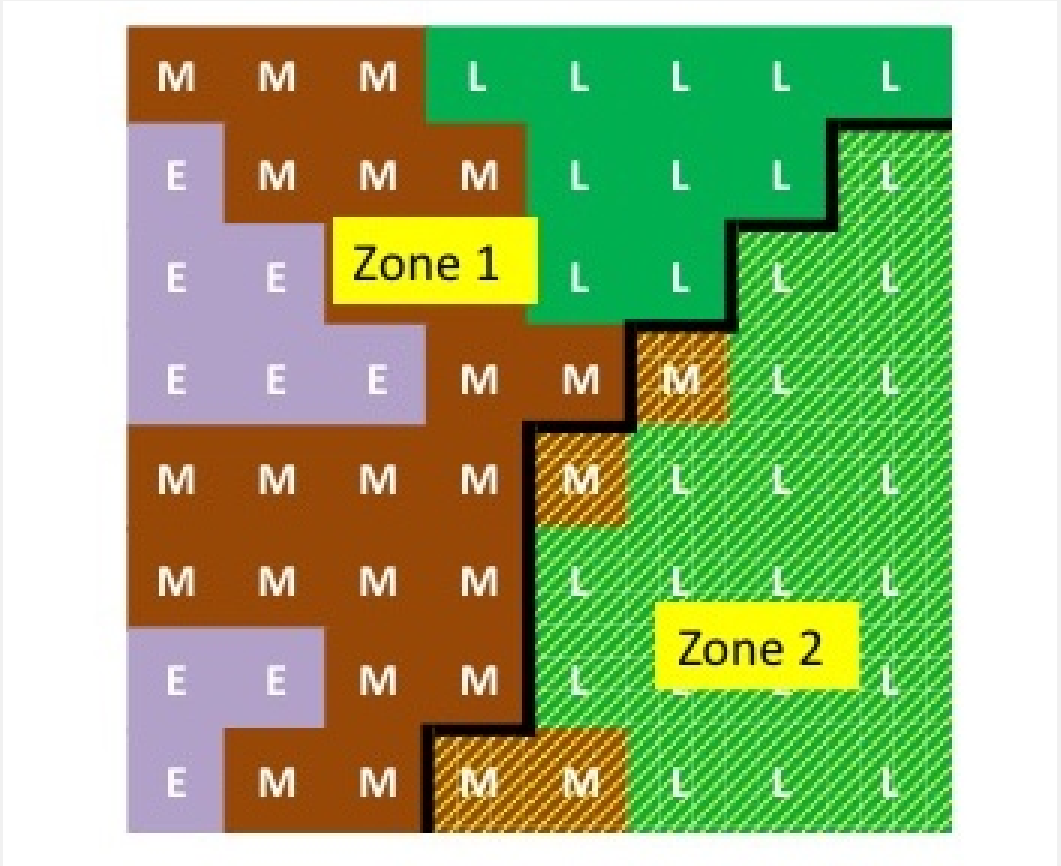
Overview of Species Distribution & State-and-Transition Simulation Modeling

State-and-Transition Simulation Models

- Optional Model Features
  - Spatial autocorrelation (e.g., clustering)
  - Spatial and/or temporal variability in transitions (e.g., jurisdictions, fire)



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Overview of Species Distribution & State-and-Transition Simulation Modeling

State-and-Transition Simulation Models

- Optional Model Features
  - Spatial autocorrelation (e.g., clustering)
  - Spatial and/or temporal variability in transitions (e.g., jurisdictions, fire)
  - Management targets (e.g., exotic species inventory and treatment)

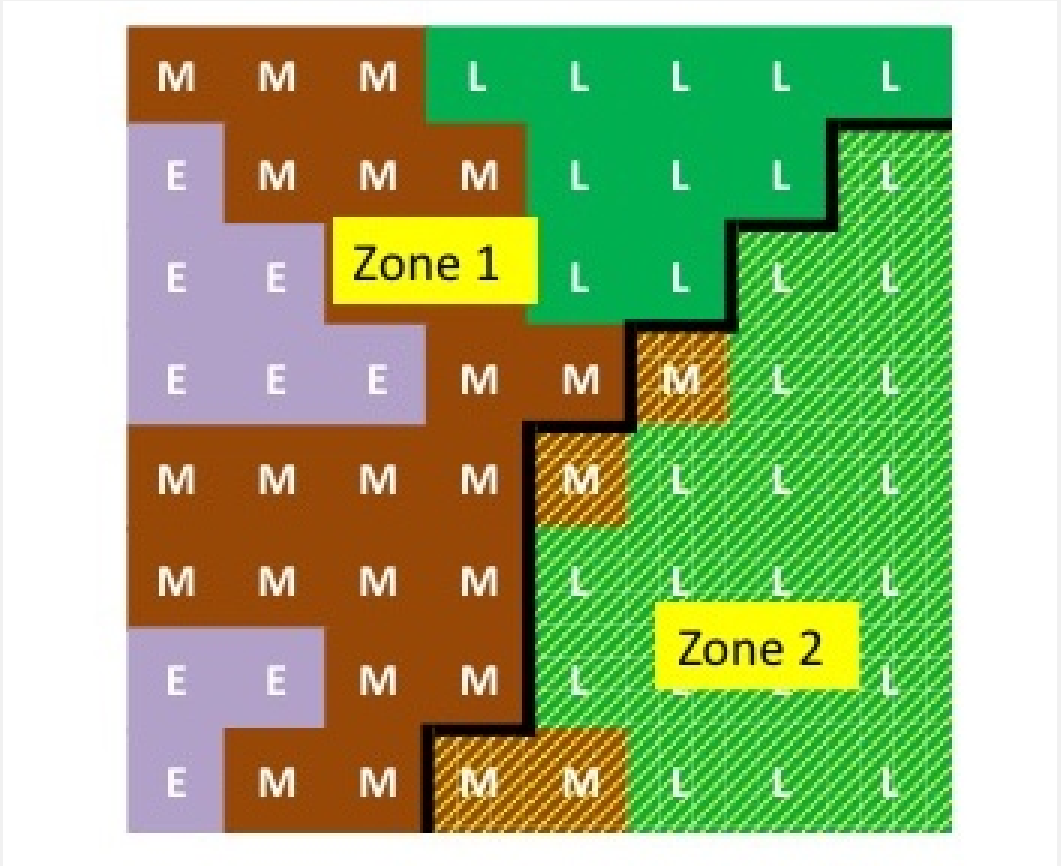

Image: L. Frid

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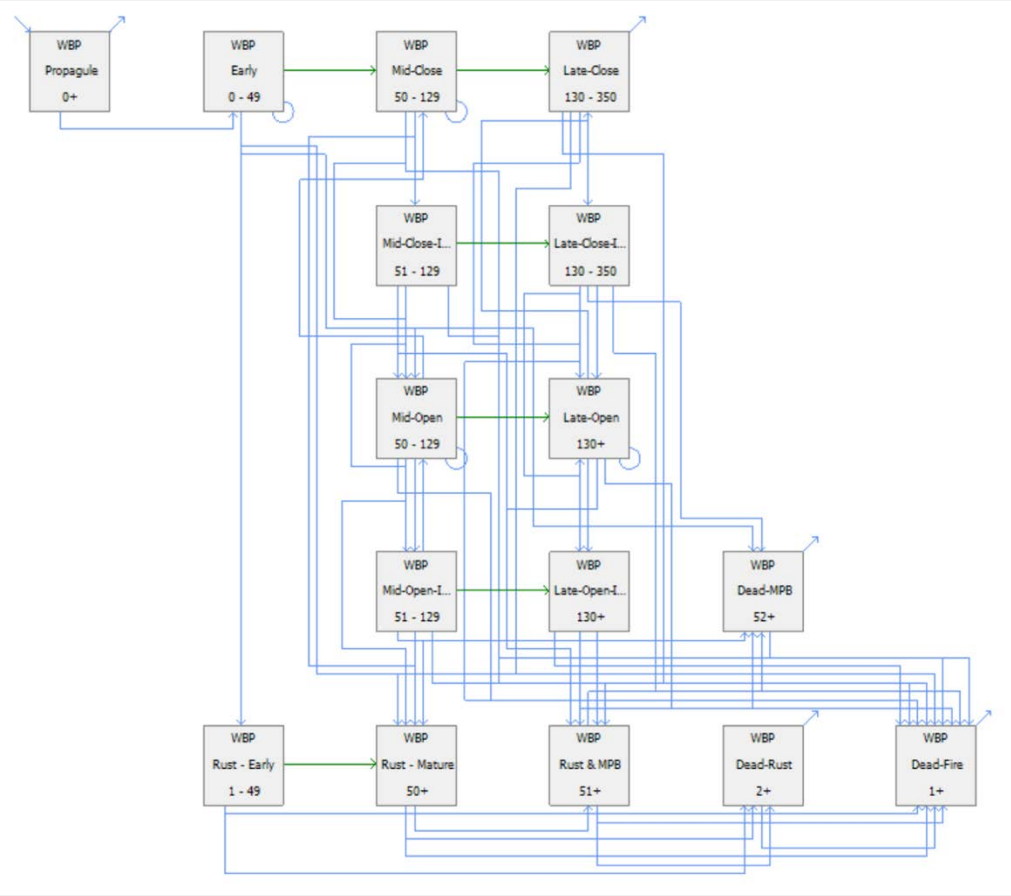
State-and-Transition Simulation Models



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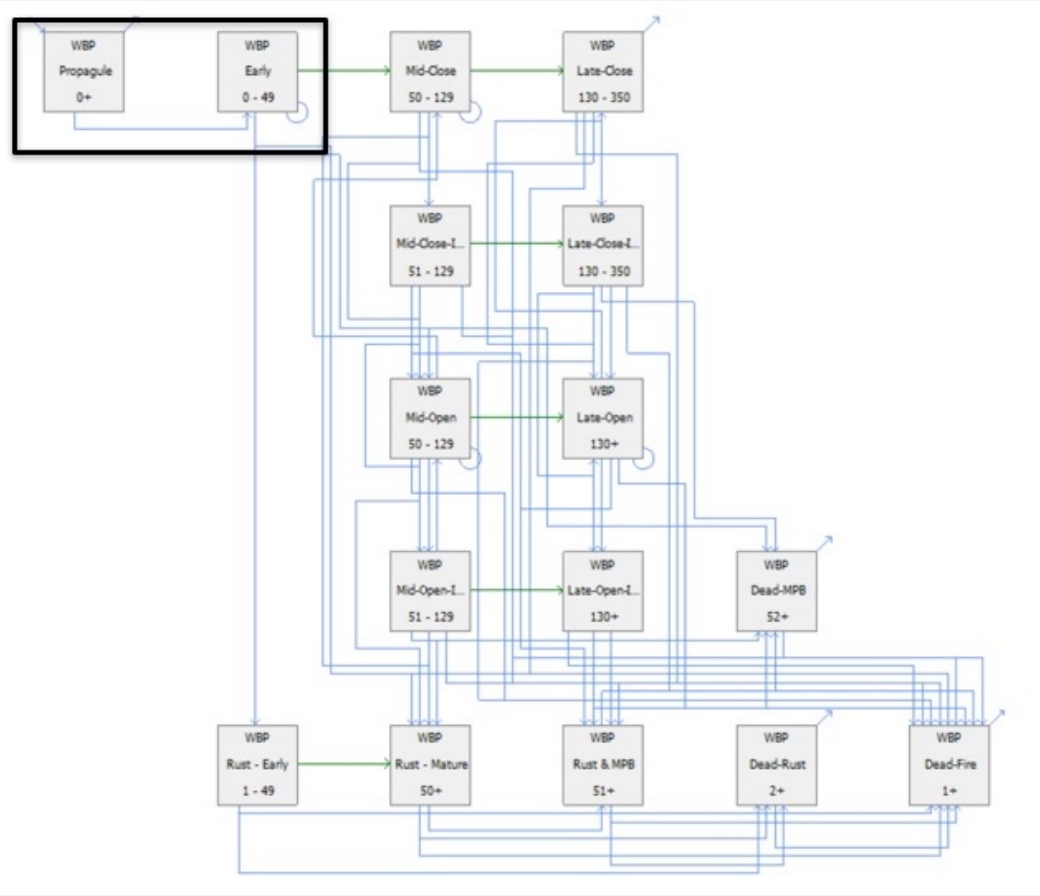
State-and-Transition Simulation Models



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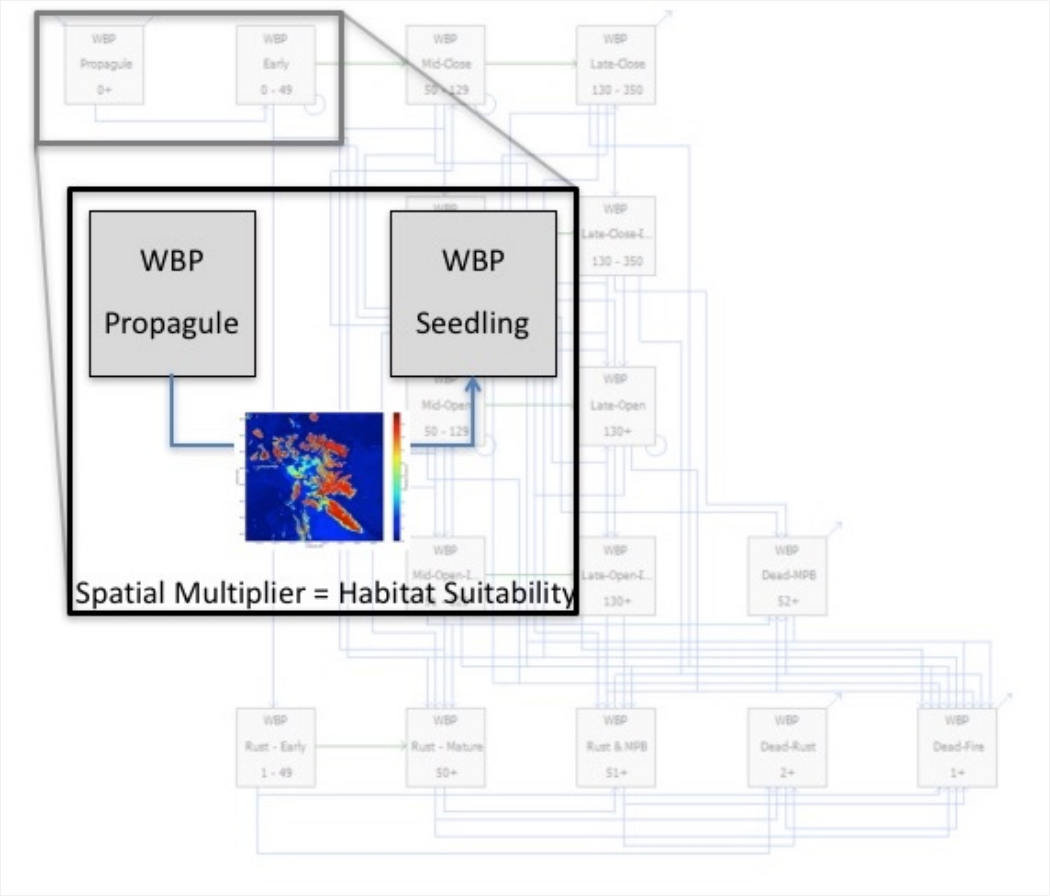
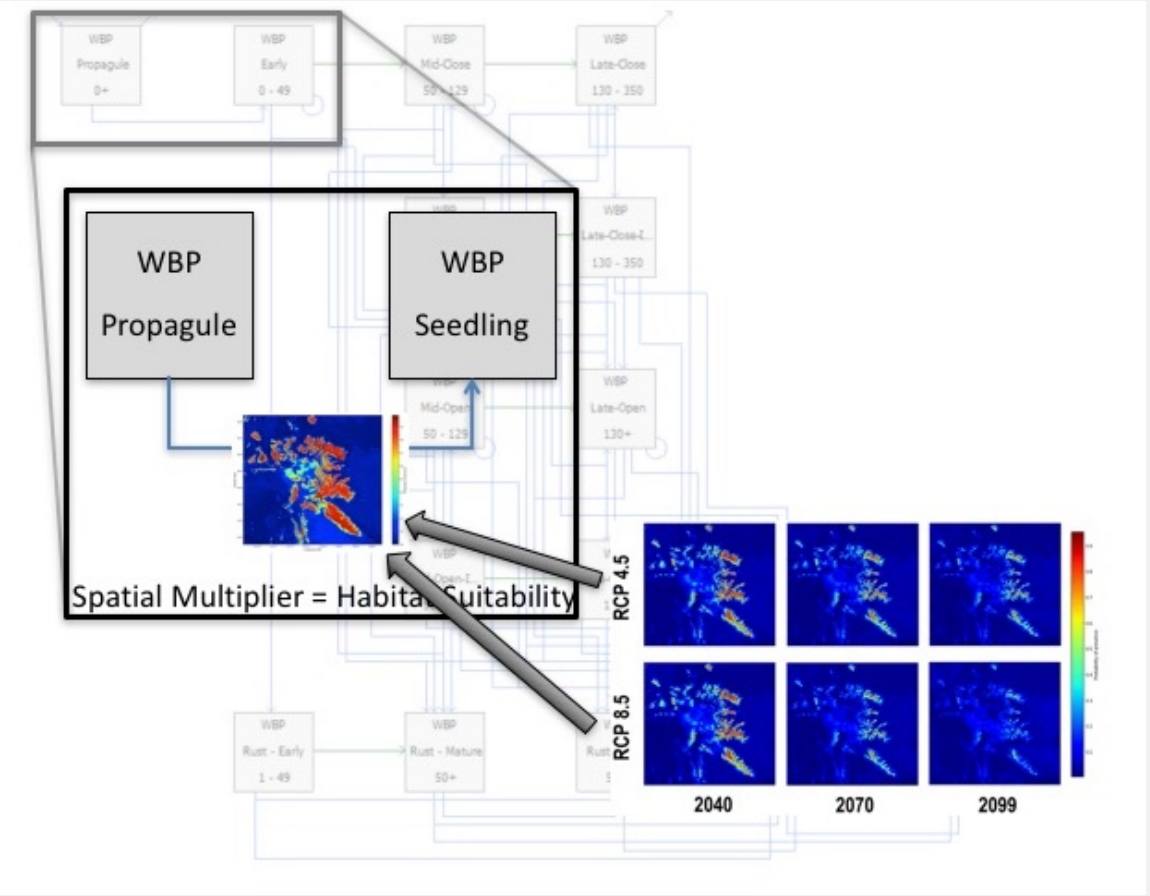
State-and-Transition Simulation Models



Miller, BW, L Frid, T Chang, N Piekielek, AJ Hansen, JT Morisette. 2015. Combining state-and-transition simulations and species distribution models to anticipate the effects of climate change. AIMS Environmental Science 2(2):400–426.

Overview of Species Distribution & State-and-Transition Simulation Modeling

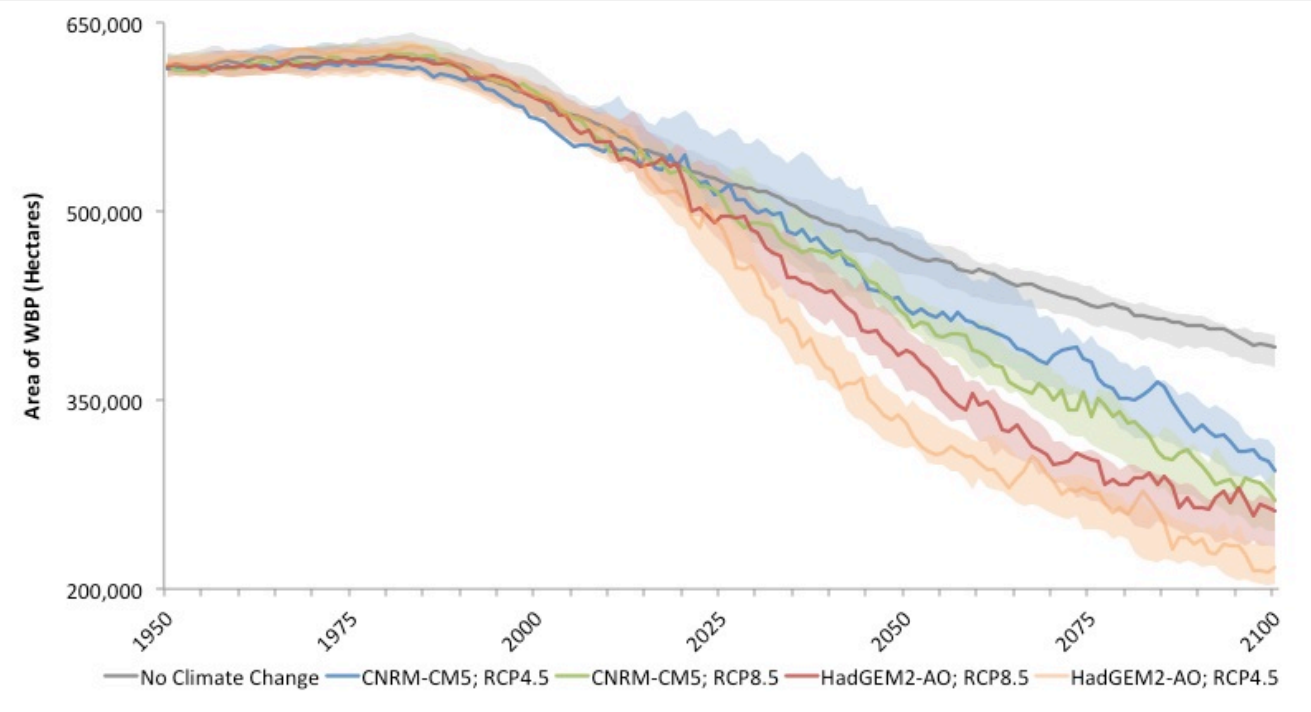
State-and-Transition Simulation Models

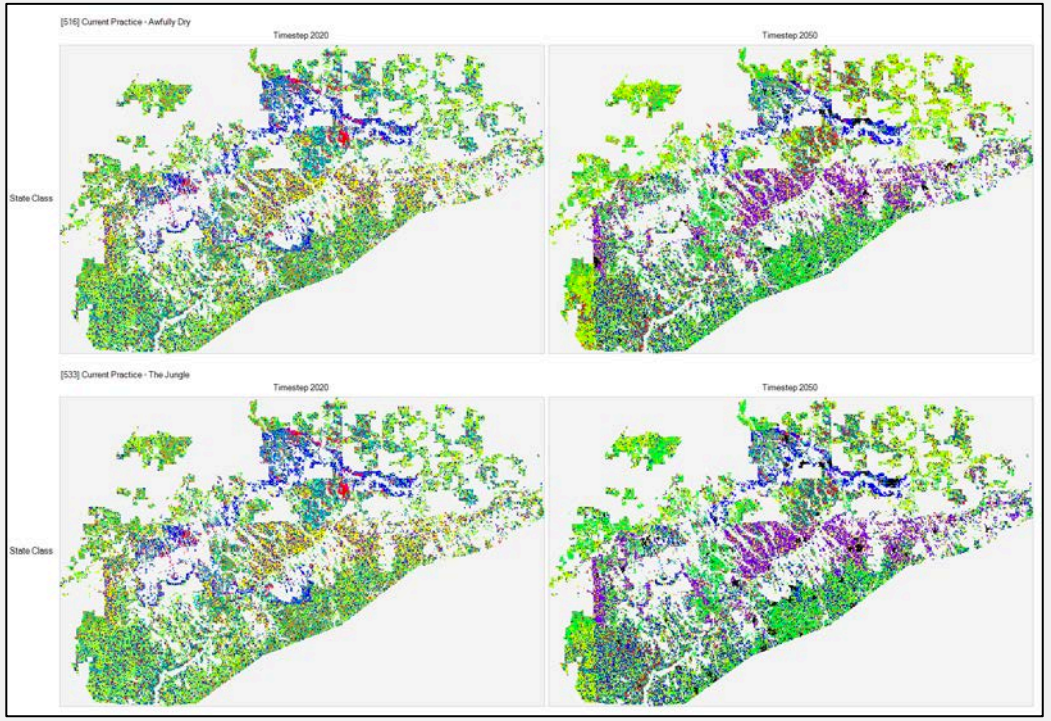


Miller, BW, L Frid, T Chang, N Piekielek, AJ Hansen, JT Morisette. 2015. Combining state-and-transition simulations and species distribution models to anticipate the effects of climate change. AIMS Environmental Science 2(2):400–426.

Overview of Species Distribution & State-and-Transition Simulation Modeling

State-and-Transition Simulation Models





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Overview of Species Distribution & State-and-Transition Simulation Modeling

ST-Sim Software

- Free software for building and running STSMs: www.apexrms.com
- Released in 2013
- Next generation of TELSA & VDDT
- 15 peer-reviewed publications since 2014

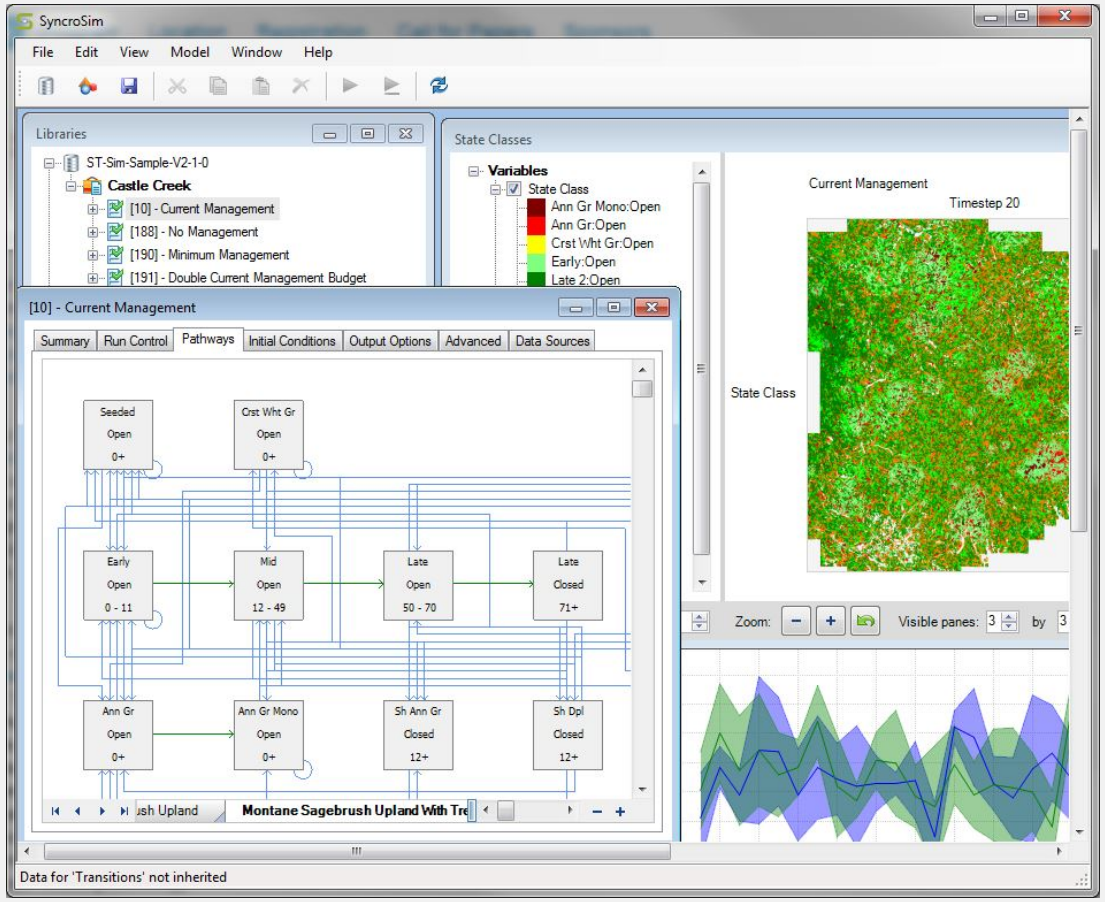
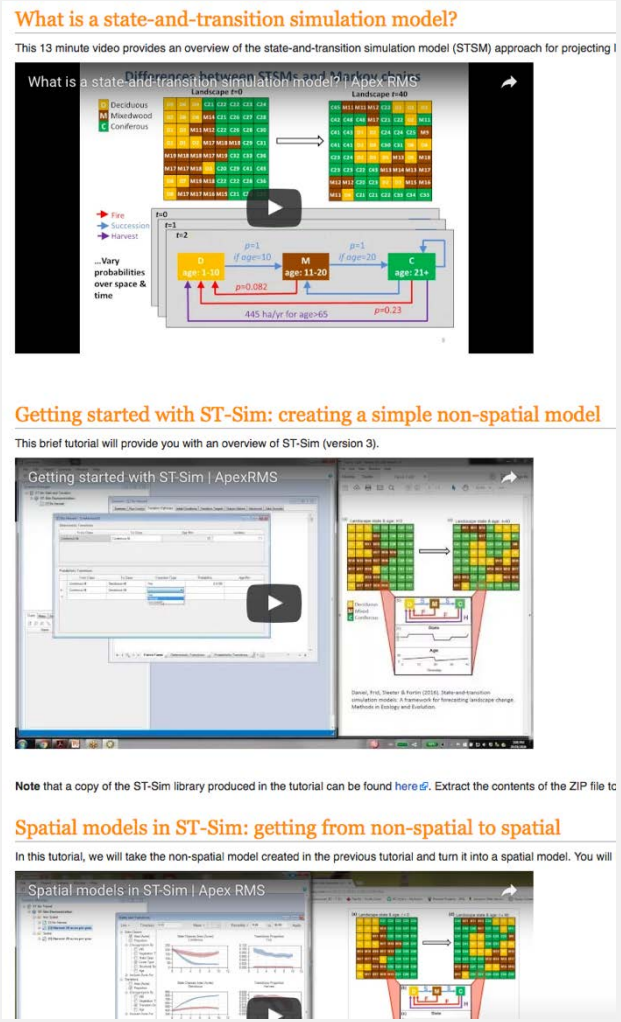


Image: L. Frid

Overview of Species Distribution & State-and-Transition Simulation Modeling

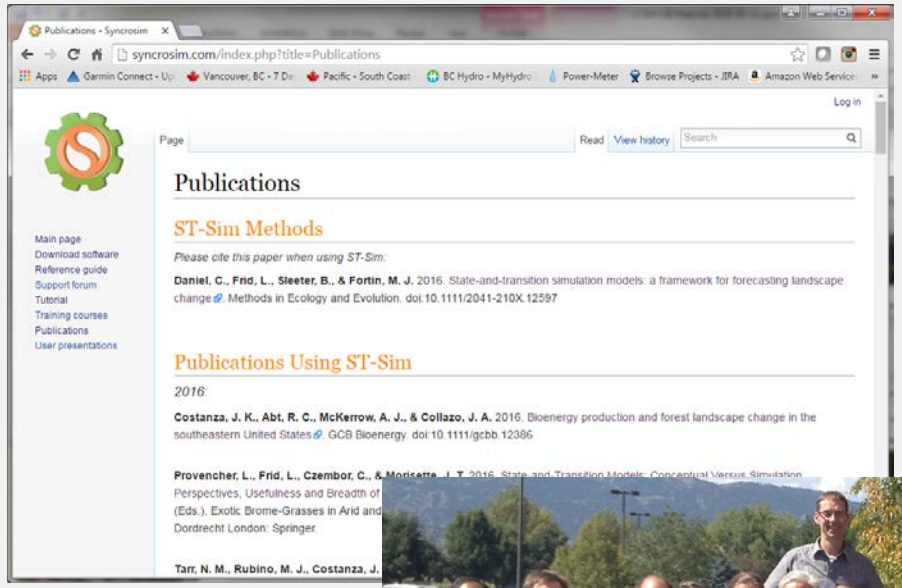
ST-Sim Software

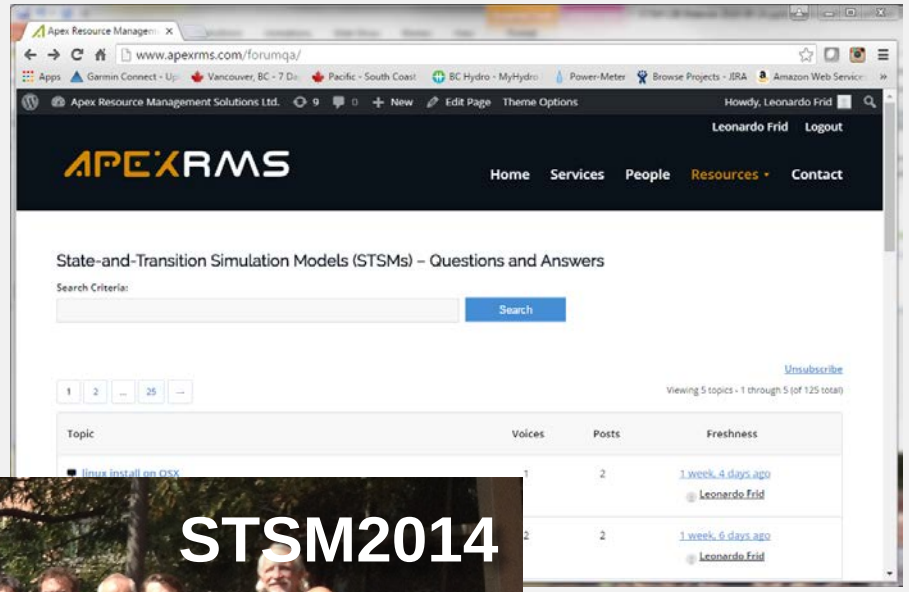
- Video Tutorials
- “SyncroSim” -> “Getting Started”
- http://syncrosim.com/index.php?title=Getting_Started



Overview of Species Distribution & State-and-Transition Simulation Modeling

ST-Sim Software



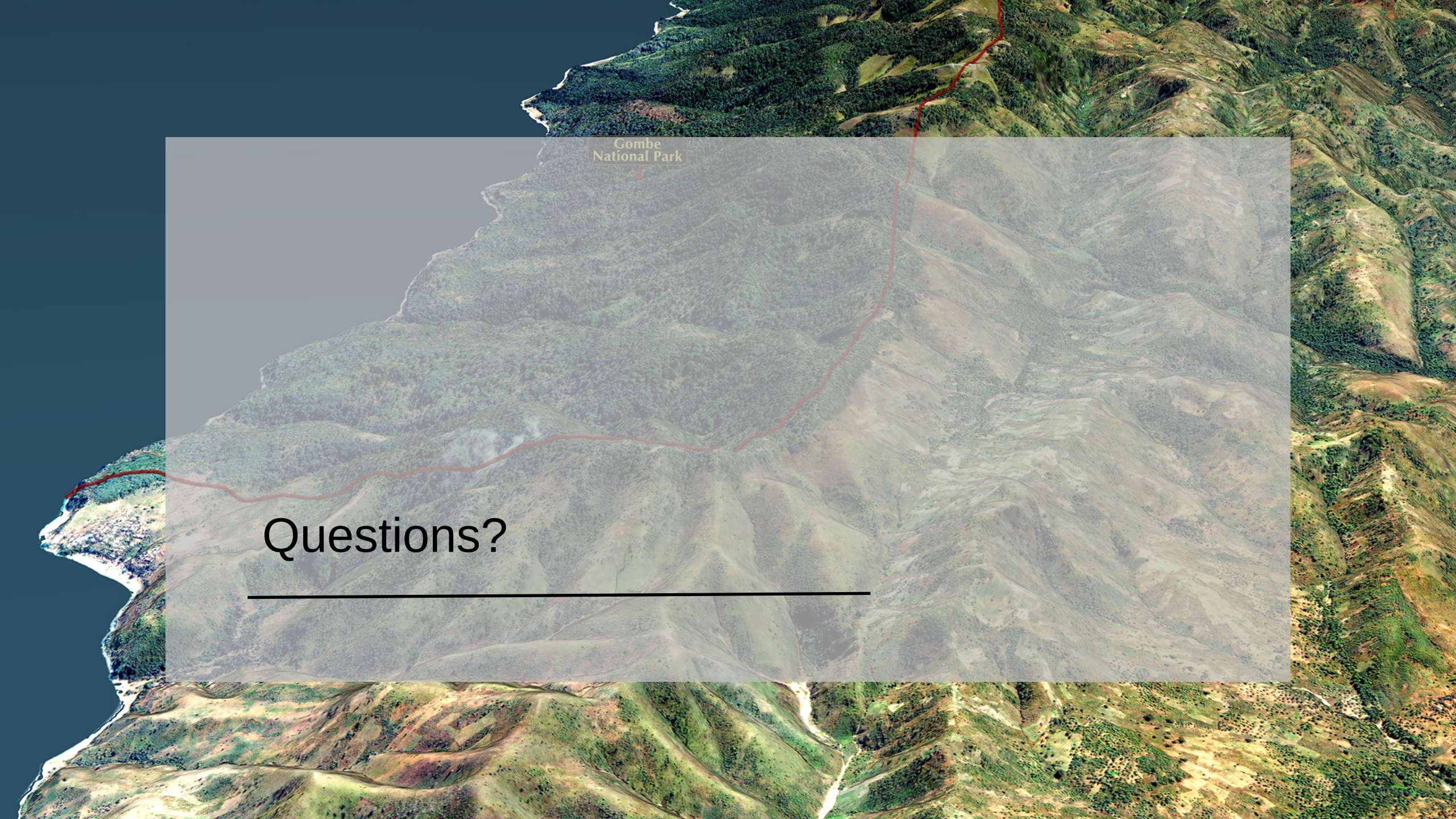


Images: L. Frid

Overview of Species Distribution & State-and-Transition Simulation Modeling

Conclusions

- State-and-Transition Simulation Models (STSMs)
  - Integrate existing knowledge
  - Identify data gaps & research priorities
  - Explore “what if” climate & management scenarios
- Simulations can leverage the strengths of other methods (e.g. species distribution modeling)



Questions?