LCC-VP

Landscape Climate Change Vulnerability Project

Using NASA Resources to Inform Climate and Land Use Adaptation

Ecological Forecasting, Vulnerability Assessment, and Evaluation of Management Options Across Two US DOI Landscape Conservation Cooperatives

The Woods Hole Research Center

Montana State University

California State University Monterey Bay

Team

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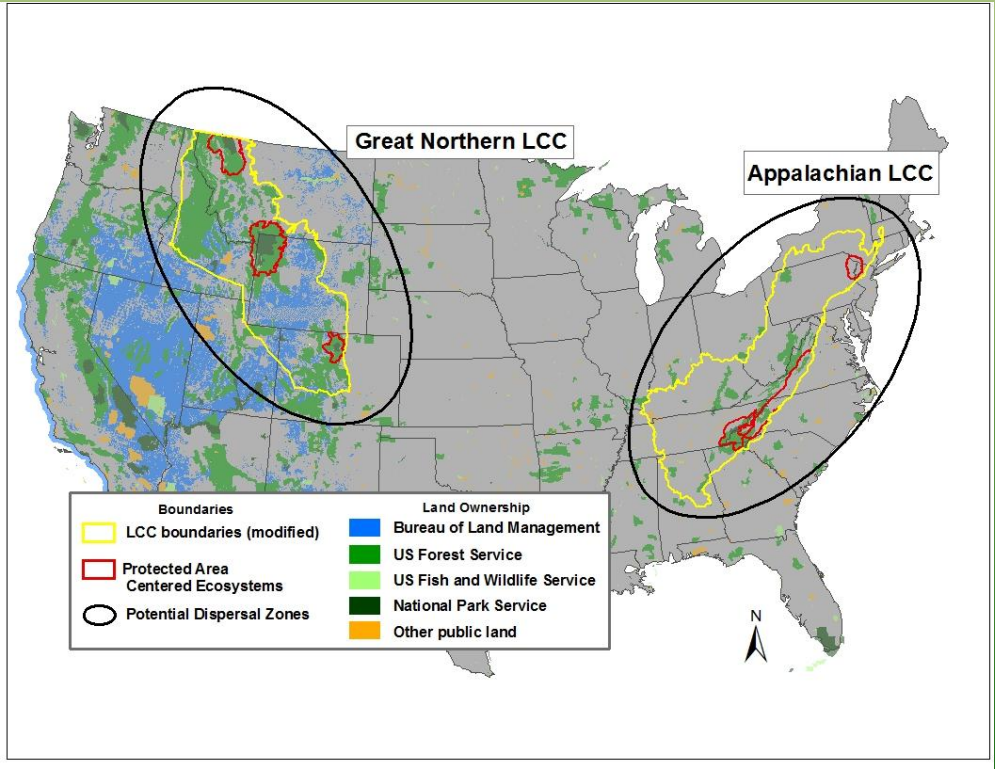
Supported by NASA Applied Sciences Program, National Park Service Inventory and Monitoring Program, and Great Northern Landscape Conservation Cooperative

Project Period: August 2011 – July 2015

Goals and Objectives

Goal

Demonstrate the four steps of a climate adaptation planning strategy in two LCCs using NASA and other data and models.

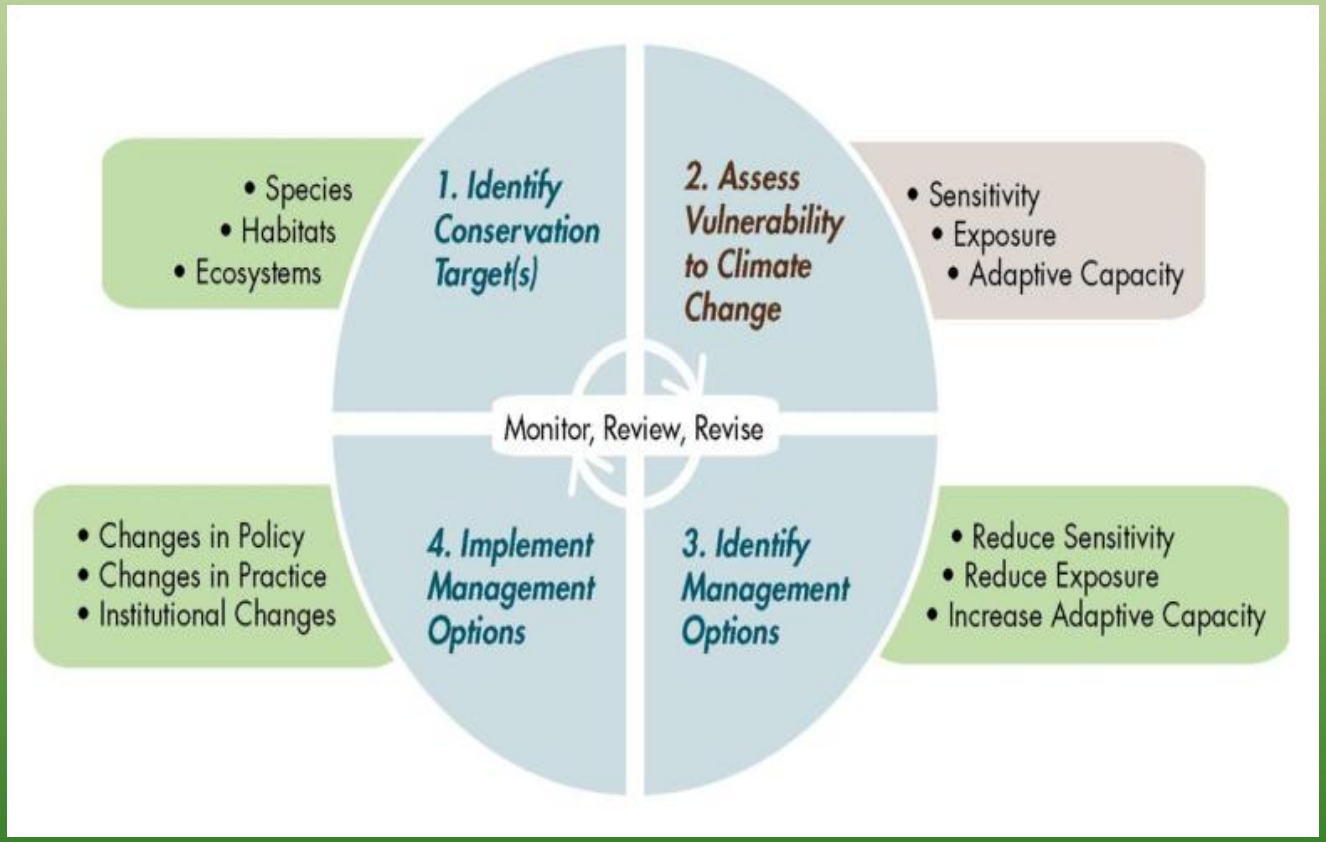


Objectives

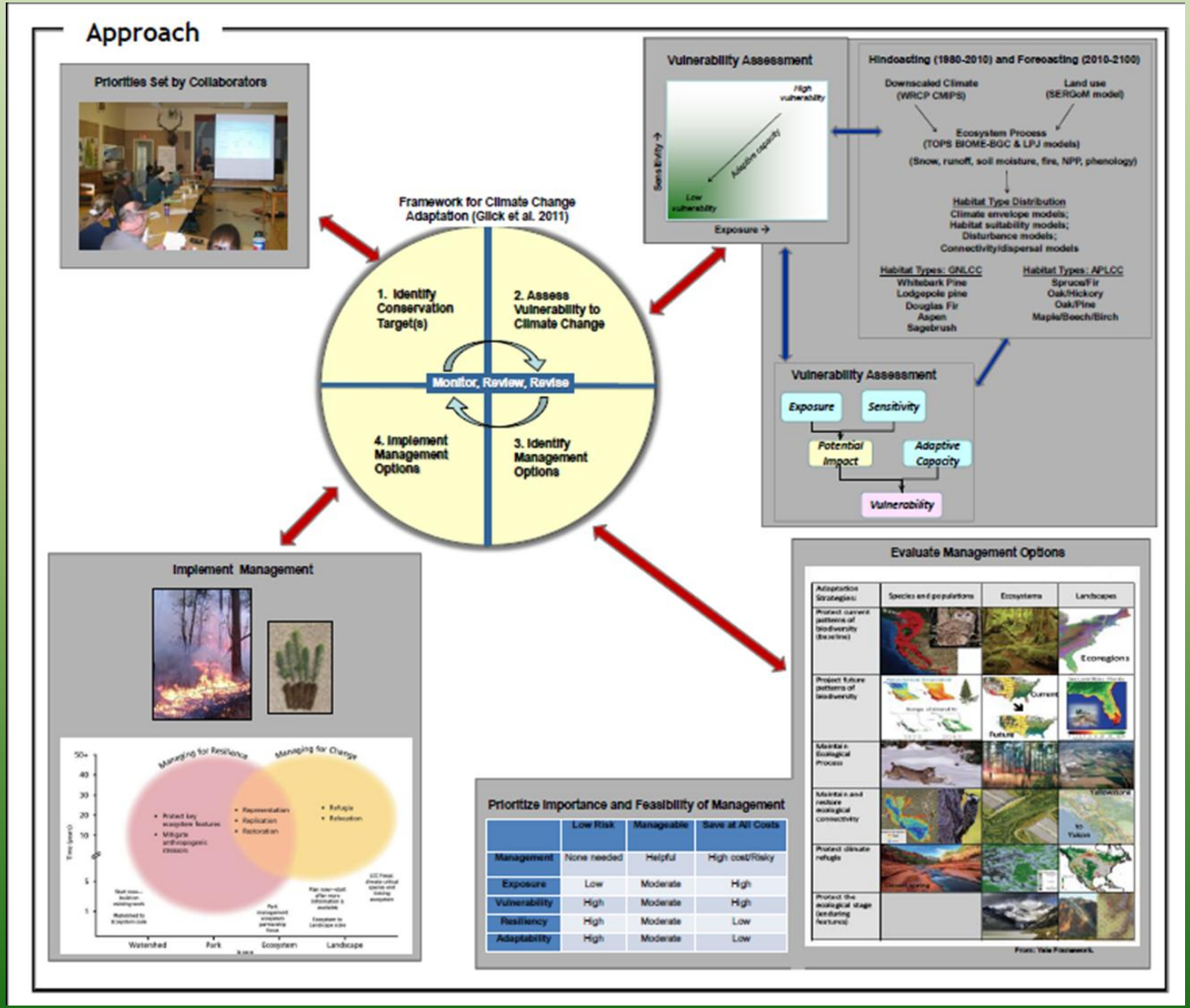
1. **Hindcast and forecast future climate and land use scenarios.**
2. **Assess the vulnerability of ecological processes and key habitat types.**
3. **Evaluate management options.**
4. **Design and deliver management adaptation strategies.**
5. **Inform decision support.**

Approach

Glick et al. 2011. Scanning the Conservation Horizon: A guide to climate change vulnerability assessment. National Wildlife Federation, Washington, D.C.



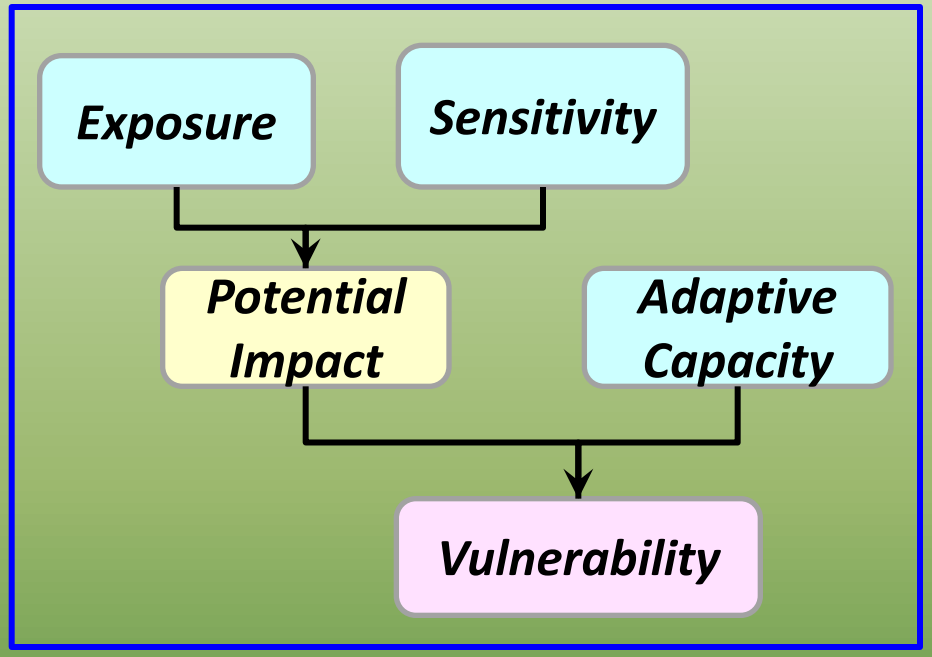
Approach


Approach
Priorities Set by Collaborators
Framework for Climate Change Adaptation (Glick et al. 2011)
1. Identify Conservation Target(s)
2. Assess Vulnerability to Climate Change
3. Identify Management Options
4. Implement Management Options
Monitor, Review, Revise
Vulnerability Assessment
High vulnerability
Adaptive capacity
Low vulnerability
Sensitivity
Exposure
Hindcasting (1980-2010) and Forecasting (2010-2100)
Downscaled Climate (WRCP CMIP5)
Land use (SERGoM model)
Ecosystem Process (TOPS BIOME-BGC & LPJ models)
(Snow, runoff, soil moisture, fire, NPP, phenology)
Habitat Type Distribution
Climate envelope models;
Habitat suitability models;
Disturbance models;
Connectivity/dispersal models
Habitat Types: GNLCC
Whitebark Pine
Lodgepole pine
Douglas Fir
Aspen
Sagebrush
Habitat Types: APLCC
Spruce/Fir
Oak/Hickory
Oak/Pine
Maple/Beech/Birch
Vulnerability Assessment
Exposure
Sensitivity
Potential Impact
Adaptive Capacity
Vulnerability
Implement Management
Managing for Resilience
Managing for Change
Protect key ecosystem features
Mitigate anthropogenic stressors
Representation
Replication
Restoration
Refugia
Relocation
Watershed
Park
Ecosystem
Landscape
Evaluate Management Options
Adaptation Strategies:
Species and populations
Ecosystems
Landscapes
Protect current patterns of biodiversity (baseline)
Ecoregions
Project future patterns of biodiversity
Current
Future
Maintain Ecological Process
Maintain and restore ecological connectivity
Yellowstone
to Yukon
Protect climate refugia
Protect the ecological stage (enduring features)
From: Yale Framework
Prioritize Importance and Feasibility of Management
Low Risk
Manageable
Save at All Costs
Management
None needed
Helpful
High cost/Risky
Exposure
Low
Moderate
High
Vulnerability
High
Moderate
High
Resiliency
High
Moderate
Low
Adaptability
High
Moderate
Low

Step 1. Identify Management Targets

STEPS	*Purpose*	*Outputs*	*Tools*
1. Select Specific Conservation Targets	• Conservation Targets are species, ecosystems, ecological processes, and cultural resources that are climate sensitive, iconic, keystone, or umbrella • This again reduces complexity by focusing on the priority resources that need to be analyzed as Conservation Targets for this exercise	Define 5-10 Conservation Targets	• Enabling Legislation; • Existing Priorities from Mgt Documents I&M Networks; • Exiting research on Climate Sensitive Resources or workshops to define Science needs • Scenario Planning Workshops • Natural Resource Condition Assessments

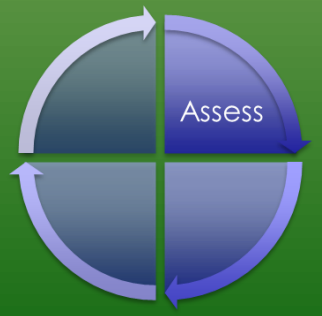
Step 2. Assess vulnerability



Exposure = magnitude & extent of change experienced

Sensitivity = degree to which fitness/process is affected

Adaptive capacity = coping responses of species/process



Step 2. Assess Vulnerability

Hindcasting (1980-2010) and Forecasting (2010-2100)

Downscaled Climate (CMIP5 / AR5)

Land use (SERGoM model)

Ecosystem Process (TOPS BIOME-BGC & LPJ models)

(Snow, runoff, soil moisture, fire, NPP, phenology)

Habitat Type Distribution

Climate envelope models;
Habitat suitability models;
Disturbance models;
Connectivity/dispersal models

Habitat Types: GNLCC

Whitebark Pine
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Spruce/Fir
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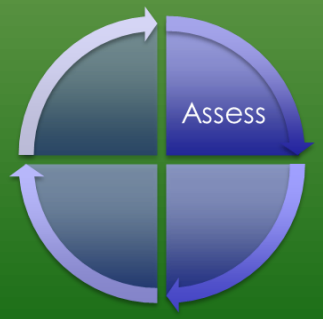
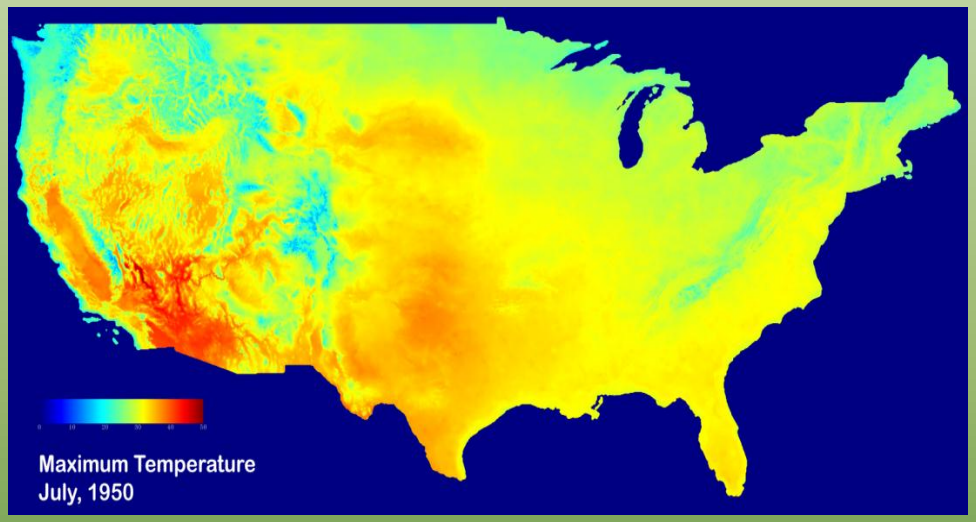


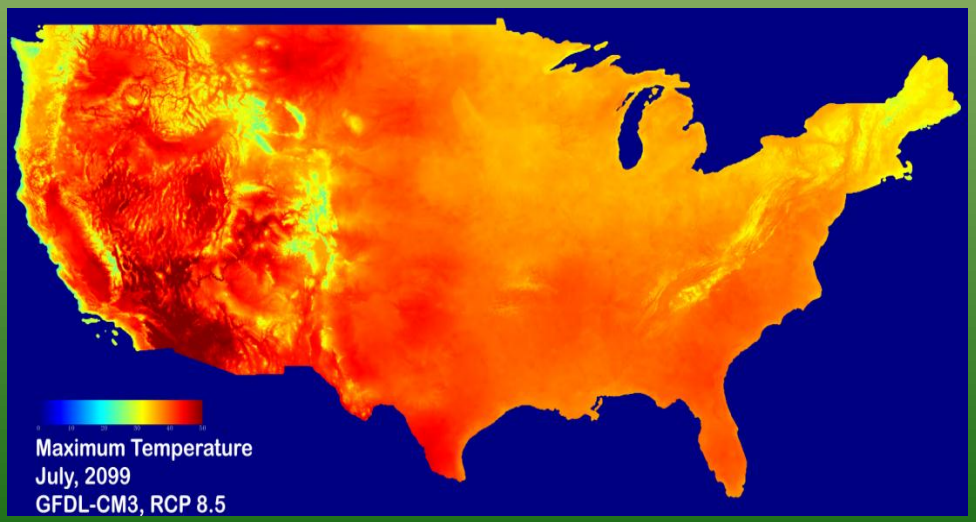
Step 2. Assess Vulnerability

Downscaled Climate Scenarios

Max temp, PRISM, July, 1950

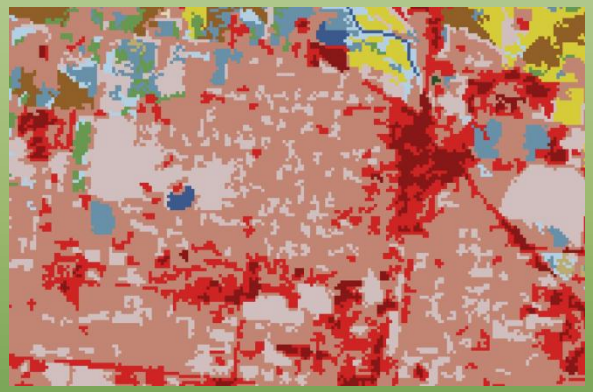


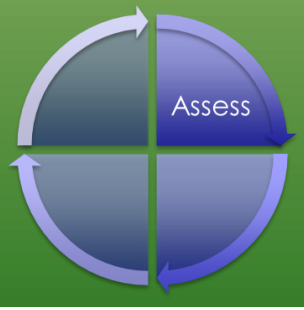
Max temp, Downscaled 800m CMIP5 GFDL-CM3, RCP 8.5, July, 2099 (Bridget Thrasher)



Step 2. Assess Vulnerability

SERGoM Land Use Change Model



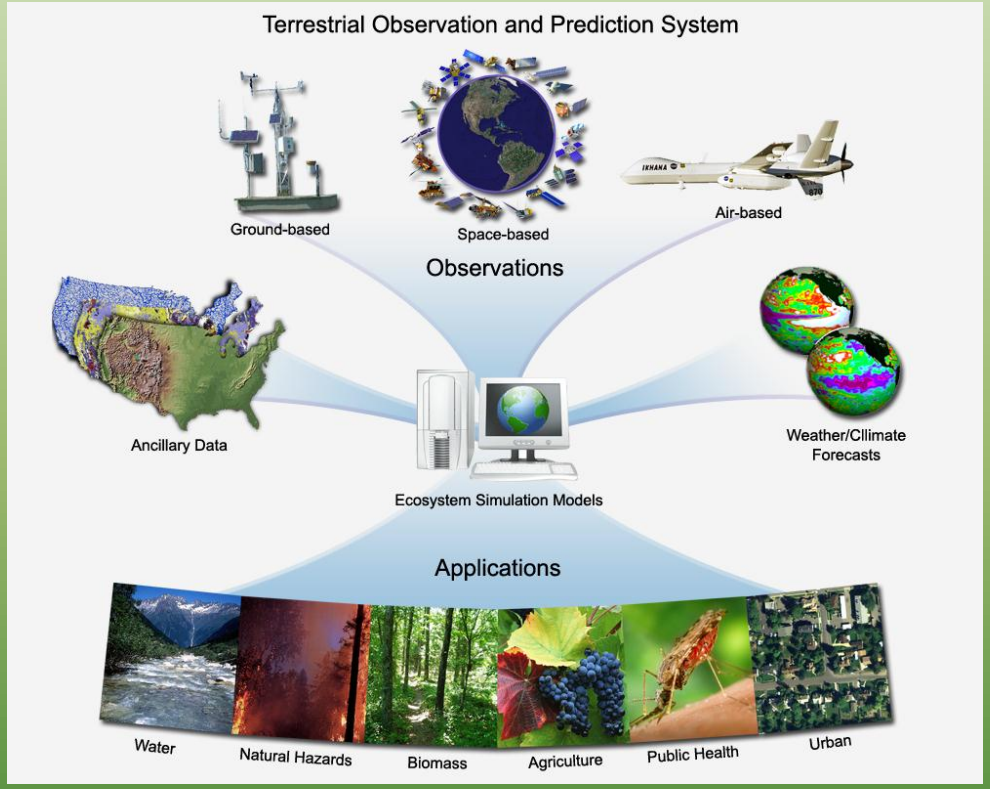


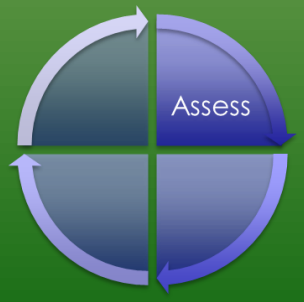
Classes have been expanded to better represent land use

Code	Group	Class Name	Description
0	Water	Lake	Natural "standing" waters
1	Water	Reservoir	"Standing" water with dam or other human structure controlling flow
2	Water	Wetlands	Wetlands
3	Protected	Recreation	National parks, natural areas, wilderness, multi-use lands, etc. (includes barren areas on public lands)
4	Working/ production	Timber	Timber production
5	Working/ production	Agriculture grazing	Grazing (and other resource extraction e.g. oil & gas)
6	Working/ production	Agriculture pastureland	Pasture
7	Working/ production	Agriculture cropland	Cropland
8	Working/ production	Mining/barren	Mineral resources (barren on private)
9	Built	Parks/open space	Parks with structures (fields, courts, golf courses, cemeteries). 0 DUA
10	Built	Residential (exurban low)	Exurban housing density 1 per 10-40 ac)
11	Built	Residential (exurban)	Exurban housing density 1 per 2.5-10 ac)
12	Built	Residential (suburban)	Housing density 1 per 0.6-2.5 ac
13	Built	Residential (medium)	Housing density 1 per 0.1-0.6 ac
14	Built	Residential (high)	Housing density 1 per >0.1 ac
15	Built	Mixed residential and commercial	Residential housing medium or higher and density of employees > xx
16	Built	Commercial	Commercial complexes, office buildings
17	Built	Industrial and utility	Industrial parks, factories, power plants, military, airports
18	Built	Institutional	Schools, churches, government complexes
19	Built	Transportation	Interstates, highways, railways

Step 2. Assess Vulnerability

TOPS Ecosystem Process Model





Vegetation Outputs
Water stress factor
Gross primary productivity
Net primary productivity

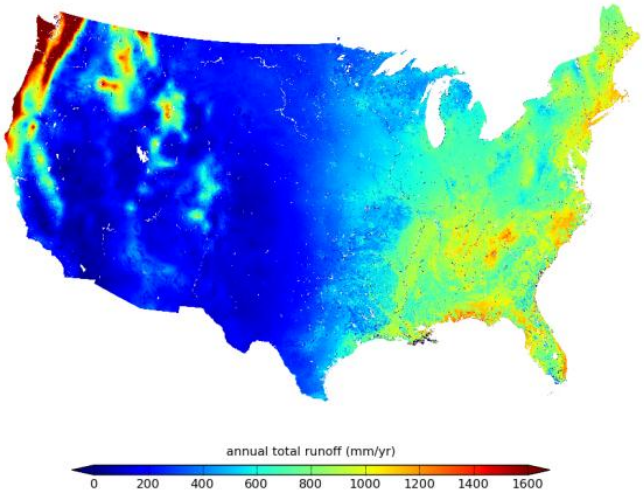
Hydrology Outputs
Outflow
Evapotranspiration
Soil water potential
Snow water equivalent
Soil moisture (VWC)

Input Parameter	United States (1km)
Impervious surface area	SERGoM (Theobald et al., 2009)
Climate (baseline run)	TopoMet Meteorological Surfaces (NTSG)
Climate (forecast)	Downscaled AR5 Scenarios, 1km resolution ensemble averages (Maurer et al., 2007) RCPs 4.5, 6.0, 8.5
Elevation	National Elevation Dataset (resampled)
Leaf Area Index (baseline run)	MODIS MOD15A2 LAI (Myneni et al., 2000)
Leaf Area Index (forecast)	Simulated by BIOME-BGC
Soils	U.S. STATSGO2 database
Land Cover	MODIS MOD12Q1 Land cover (Friedl et al., 2002)

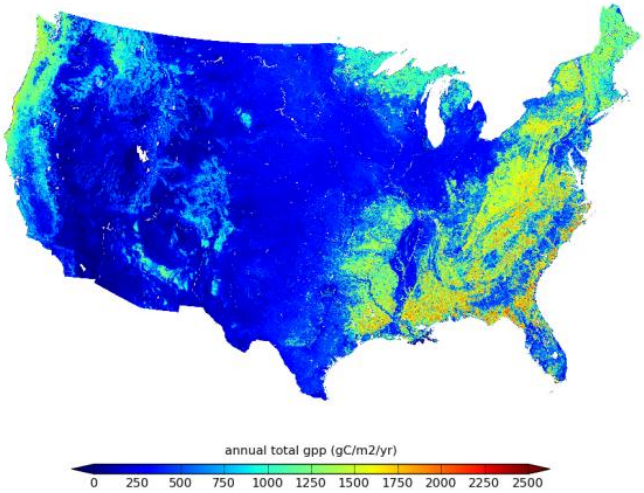
Step 2. Assess Vulnerability

TOPS Results

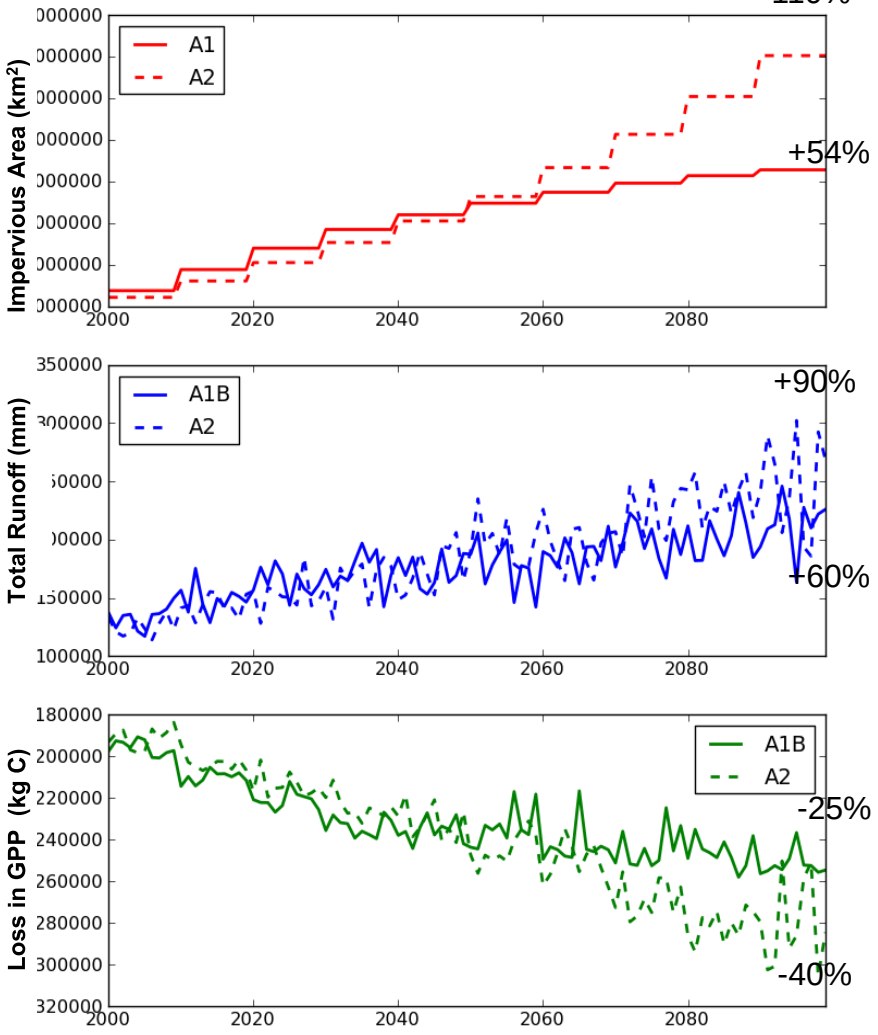
2100 Runoff



2100 GPP

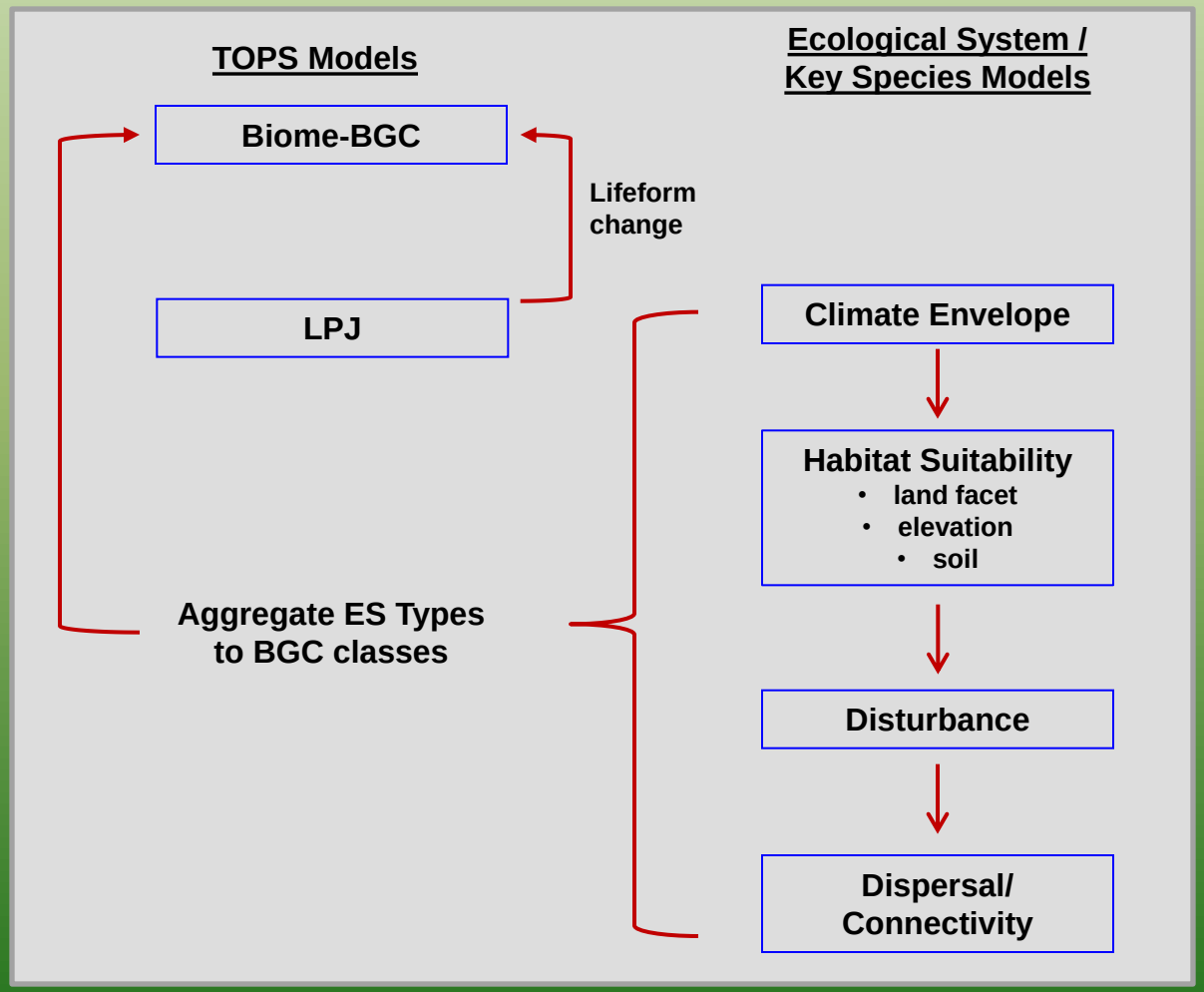


Coupled climate and land use change impacts over urban areas



Step 2. Assess vulnerability

Linking Vegetation and Process Models



Step 2. Assess vulnerability

Linking Vegetation and Process Models

TOPS Models

Biome-BGC

Lifeform change

LPJ

Aggregate ES Types to BGC classes

Ecological System / Key Species Models

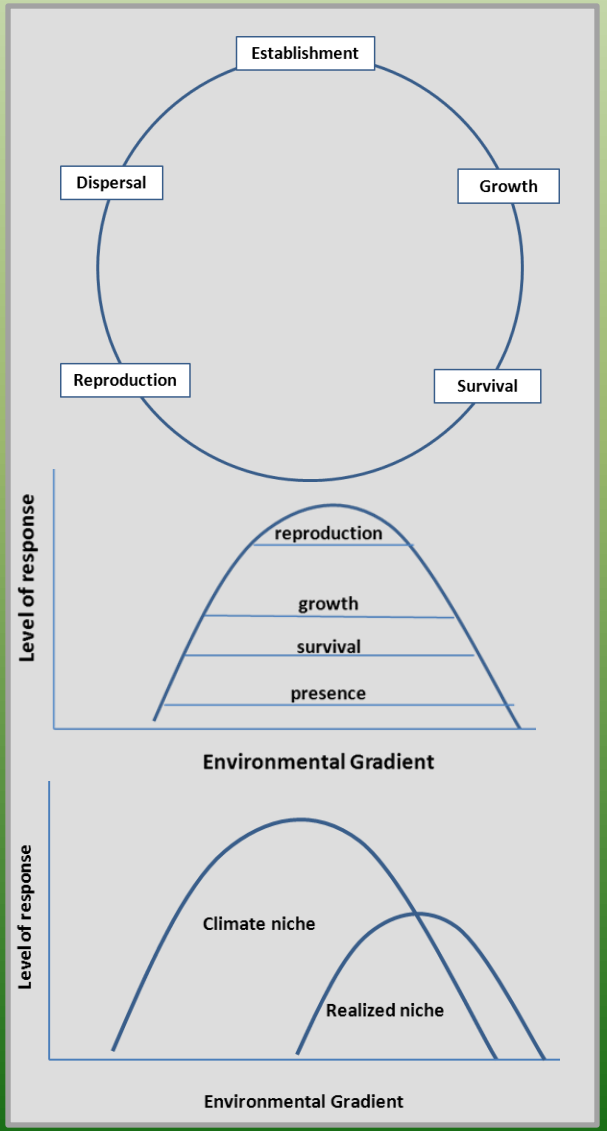
Climate Envelope

Habitat Suitability
- land facet
- elevation
- soil

Disturbance

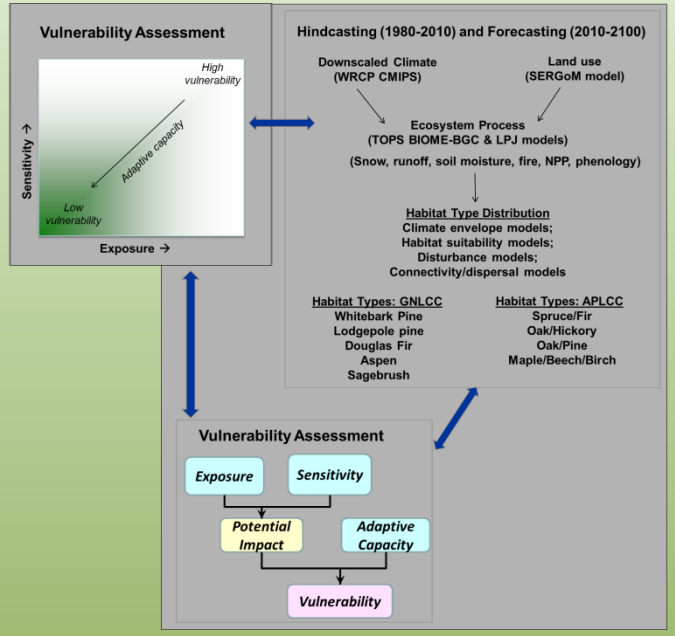
Dispersal/ Connectivity

Niche-based Approach

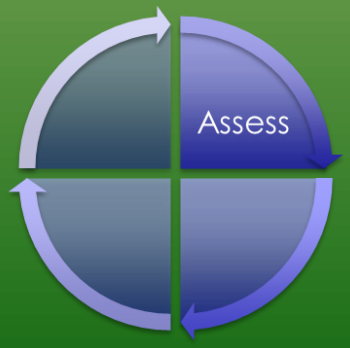


Step 2. Assess Vulnerability

Crosswalk Forecasting Results in Vulnerability Assessment

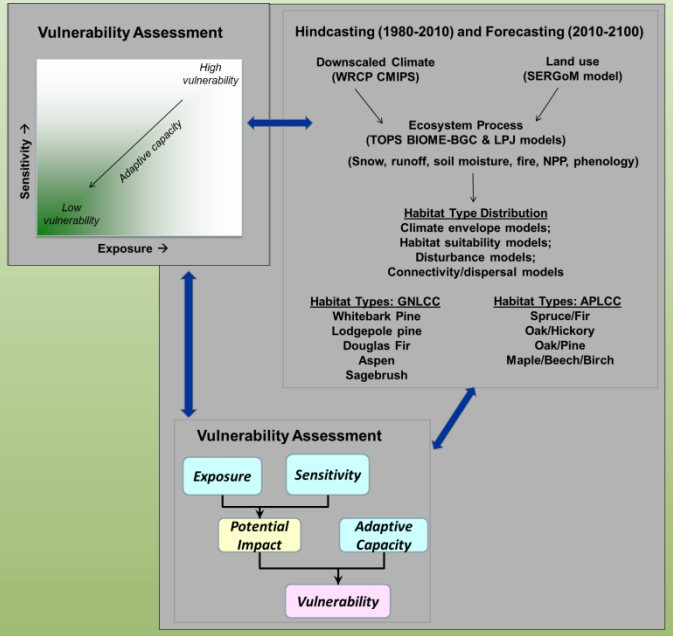


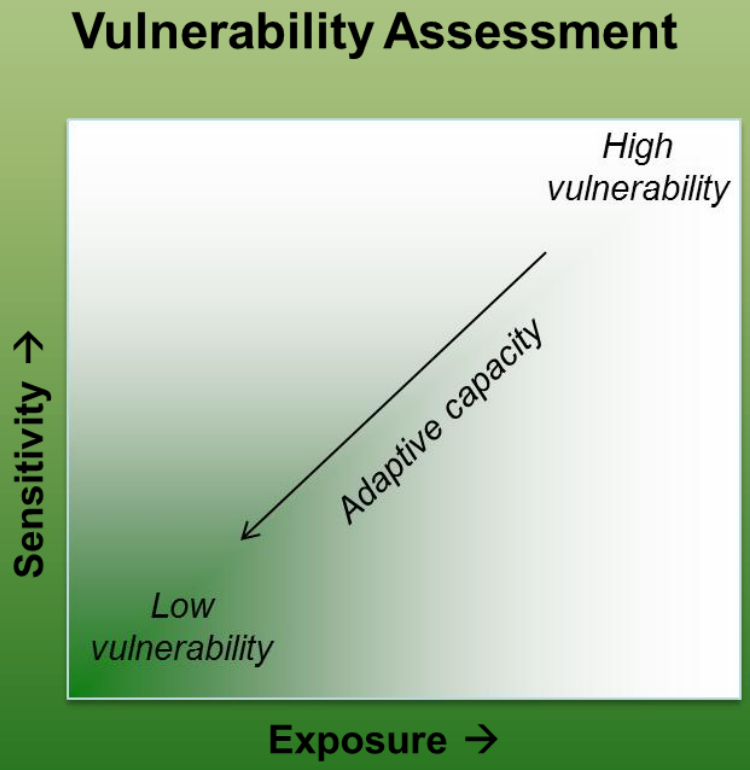
Component of Vulnerability	Species / Communities	Ecological System (ES)	Biomes
Exposure	Climate (TOPS) and land use (SERGoM) projections	Climate (TOPS) and land use (SERGoM) projections	Climate (TOPS) and land use (SERGoM) projections
Sensitivity	Bioclimate modeling; Dynamic vegetation modelling	Climate space modeling; TOPS projections	Biome BGC projections; controls of NPP; ecosystem model responsiveness
Adaptive Capacity	Species & habitat traits	Landscape facets; ecosystem modifications; connectivity; protection	Diversity at Ecological System level; conservation context

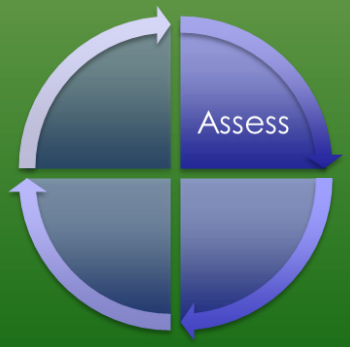


Step 2. Assess vulnerability

Adaptive Capacity

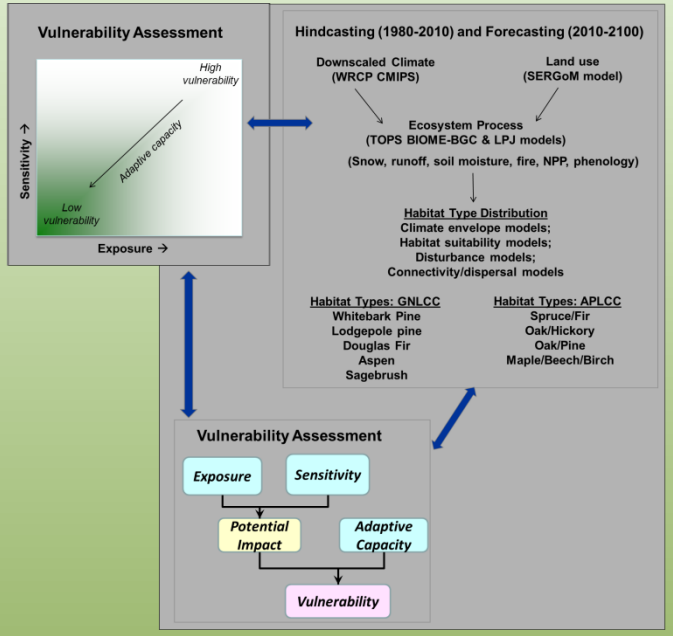


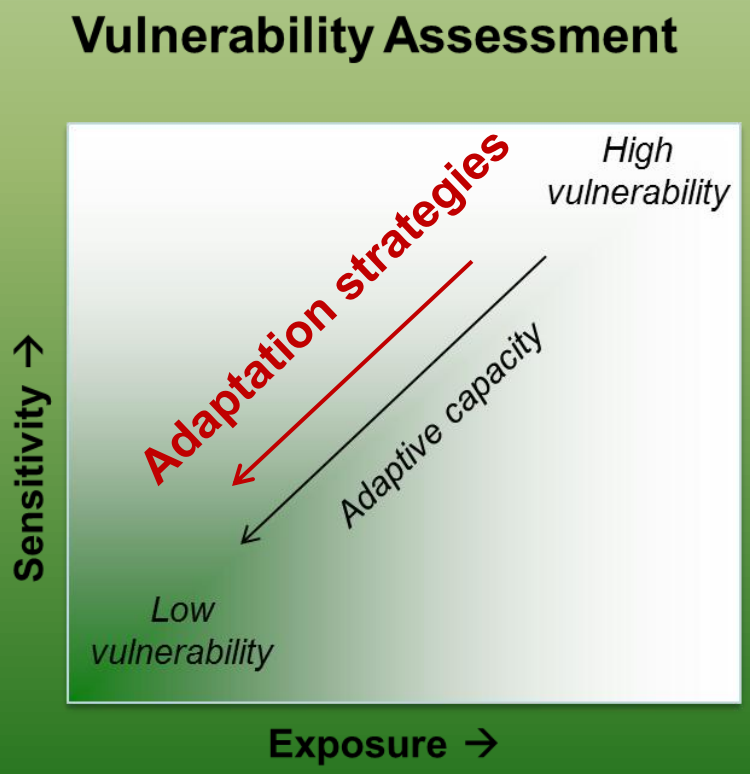


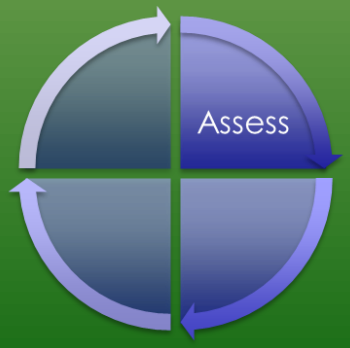


Step 2. Assess vulnerability

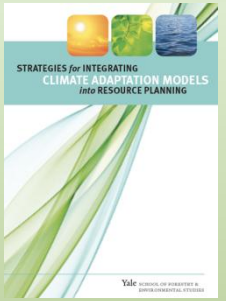
Adaptive Capacity





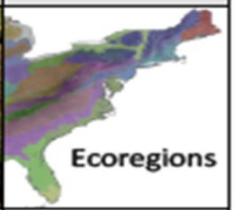
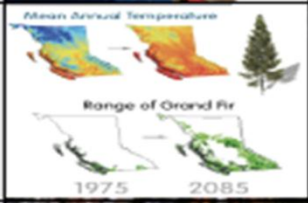
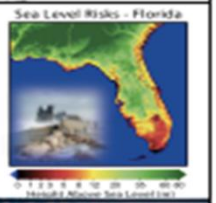
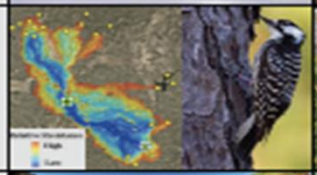
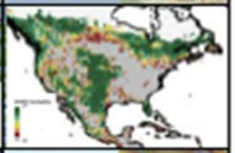
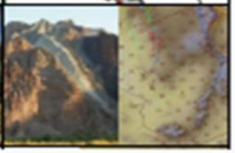


Step 3. Management Options



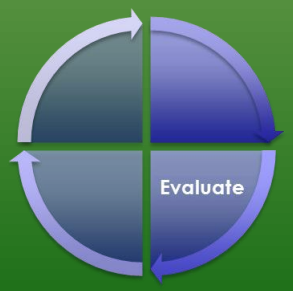
Identify Management Options

www.databasin.org/yale

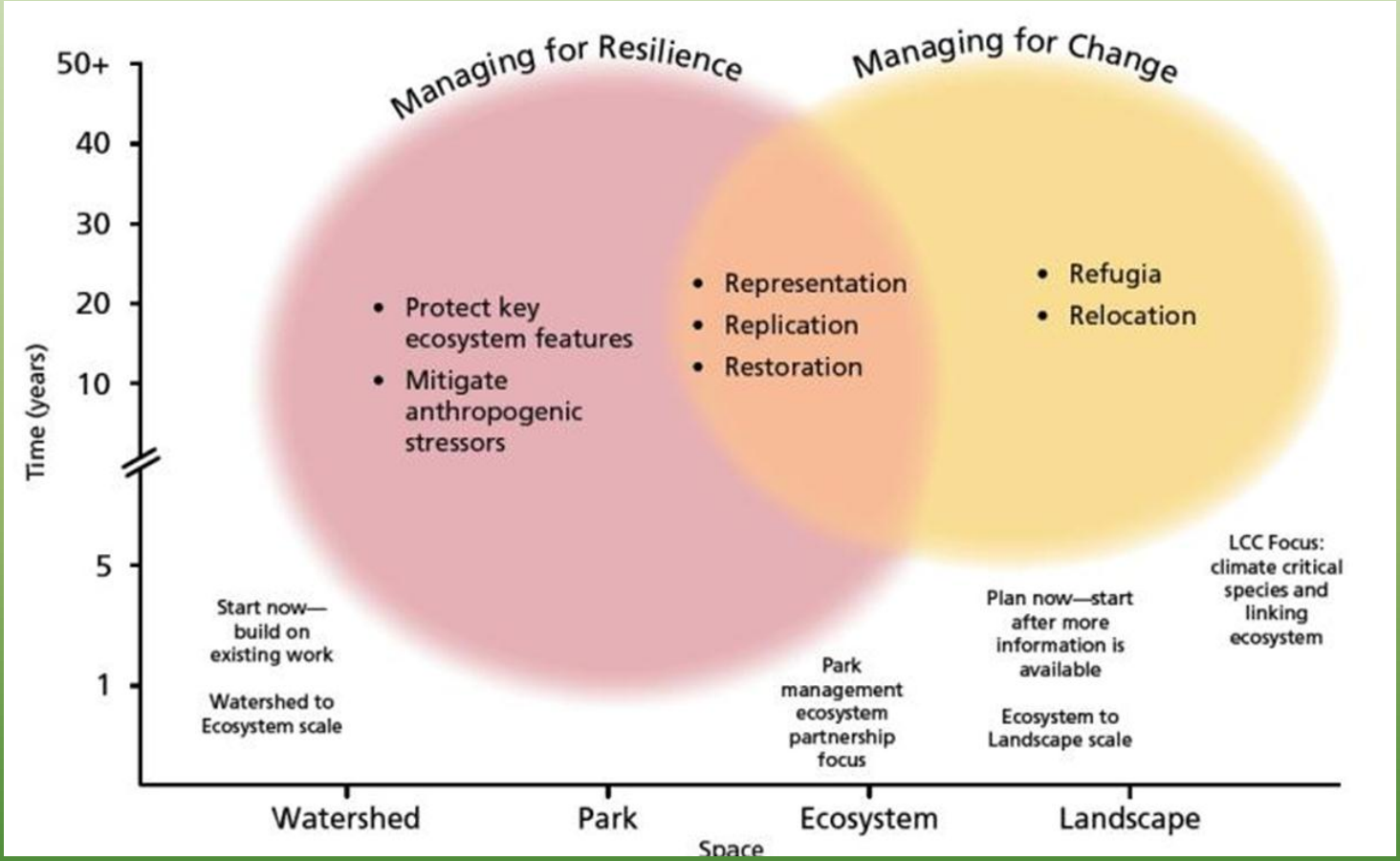
Adaptation Strategies:	Species and populations	Ecosystems	Landscapes
Protect current patterns of biodiversity (baseline)			
Project future patterns of biodiversity			
Maintain Ecological Process			
Maintain and restore ecological connectivity			
Protect climate refugia			
Protect the ecological stage (enduring features)			

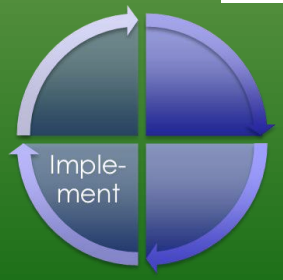
Evaluate Management Options

	Low Risk	Manageable	Save at High Cost
Management	None needed	Helpful	High cost/Risky
Exposure	Low	Moderate	High
Vulnerability	High	Moderate	High
Resiliency	High	Moderate	Low
Adaptability	High	Moderate	Low



Step 4. Deliver Management Strategies

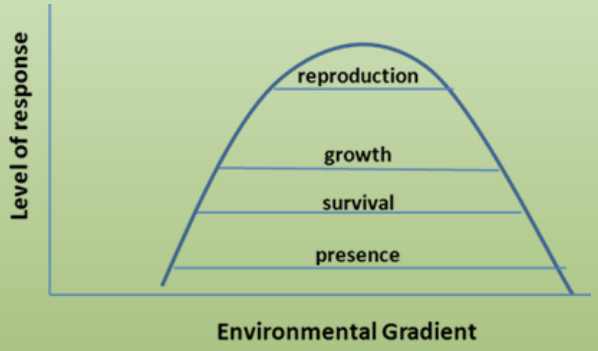




Example: Whitebark Pine in GYE

Overview

- Keystone species
- Declining dramatically
- Listed as Candidate species
- Grizzly bear relisted



Management Questions

- Range change under future climate?
- Settings allowing reproduction?
- Where to focus treatment of competitors, translocation?

Collaborators

Greater Yellowstone Coord. Comm.

Decision Support

Decision Support Product	Spatial Scale		
	LCC	Greater Ecosystem	Mgt. Unit
Data layers (e.g.): • downscaled climate SERGoM projections, • TOPS and biodiversity outputs	X	X	X
Development of metrics for conservation targets (e.g.): • permeability • biodiversity index	X		
Syntheses reports (e.g.): • downscaled climate • land use change • Vegetation response	X	X	
Test theory of V.A. at scales relevant to management		X	X
Development of climate adaptation options		X	X
Implementation of strategies			X
Demonstration of full four-step vulnerability assessment.	X		
Training on overall approach	X	X	X

Current Status

Current Status

The project is the first year of the four-year funding period.

Year 1: Refine study approach; engage key collaborators; compile data sets; validate models

Year 2: Do ecological hindcasts and forecasts; model habitat types; assess vulnerability in GNLCC with cooperators.

Year 3: Do management evaluation and implementation in GNLCC; assess vulnerability in APLCC with cooperators.

Year 4: Do management evaluation and implementation in APLCC; technology and data transfer; final reporting.

Acknowledgments

Funds for the project are provided by the NASA Applied Sciences Program under the Biological Response to Climate Change Initiative. In-kind support is provided by the National Park Service Inventory and Monitoring Program and the Great Northern LCC. Collaborators include: Mike Britten, NPS I&M Rocky Mountain Network; Jim Comiskey, NPS I&M Mid-Atlantic Network; Keith Langdon, Great Smoky Mountain National Park I&M Coordinator; Matt Marshall, NPS I&M Eastern Rivers and Mountains Network; Jim Schnerbl, Shenandoah National Park; David Thoma, NPS I&M Yellowstone Network.

http://www.montana.edu/lccvp/index.html

Proposed Vegetation Modeling

- We will focus on the coarser biodiversity levels in order to make initial progress. E.g. land facets, vegetation lifeforms, and ecological system types

- **Coarse filter**
  - Climate envelope modeling of major **ecological system types** in the ALCC (e.g. South-Central Interior Mesophytic Forest, Appalachian (Hemlock-) Northern Hardwood Forest)
  - Serves two purposes

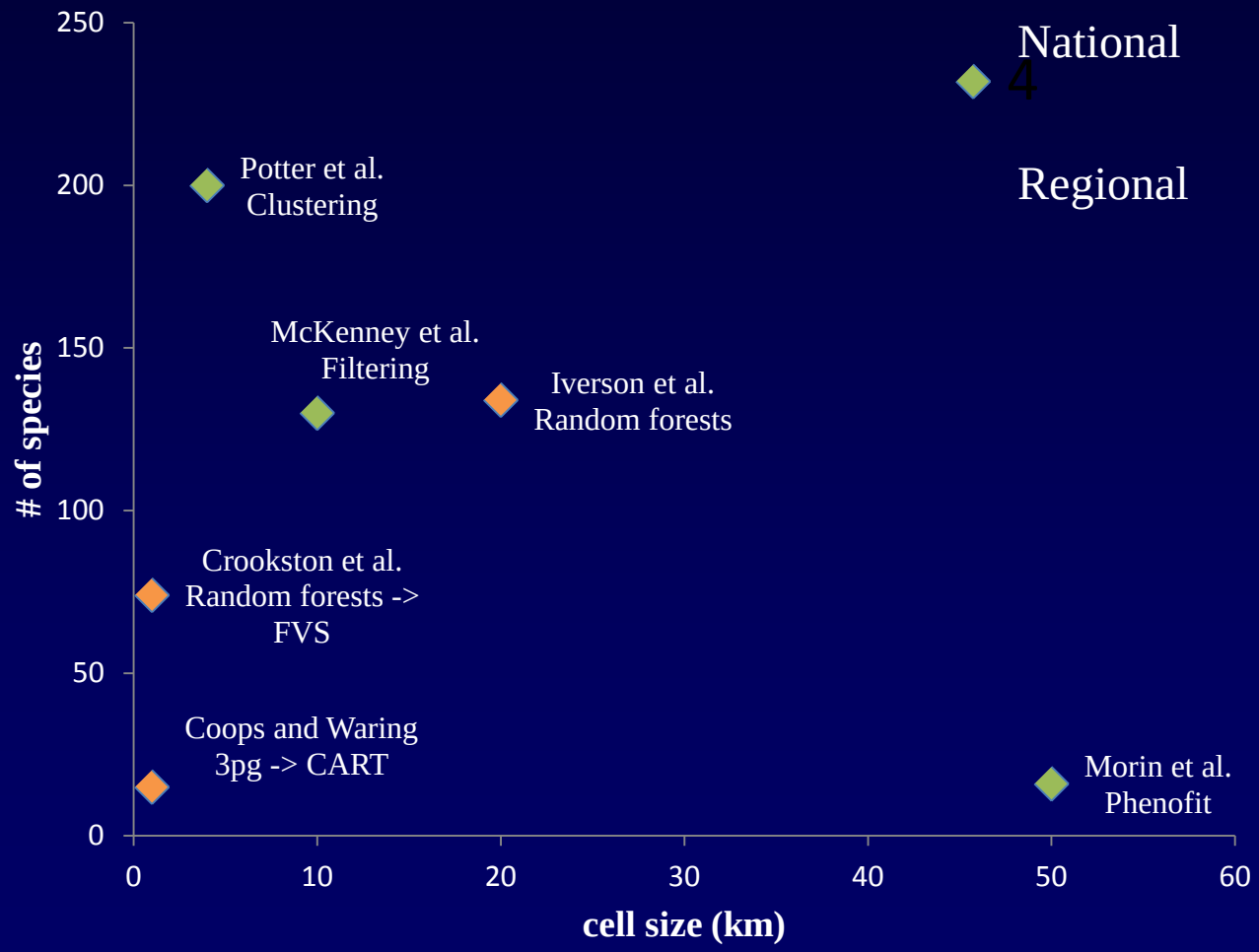
    1) Generate scenarios of broad scale ecological reorganization in response to climate and land use change

    2) Inform **ecological process modeling** (Biome-BGC) so that process model outputs (e.g. GPP, plant water stress) reflect changes in vegetation type predicted by climate envelope models

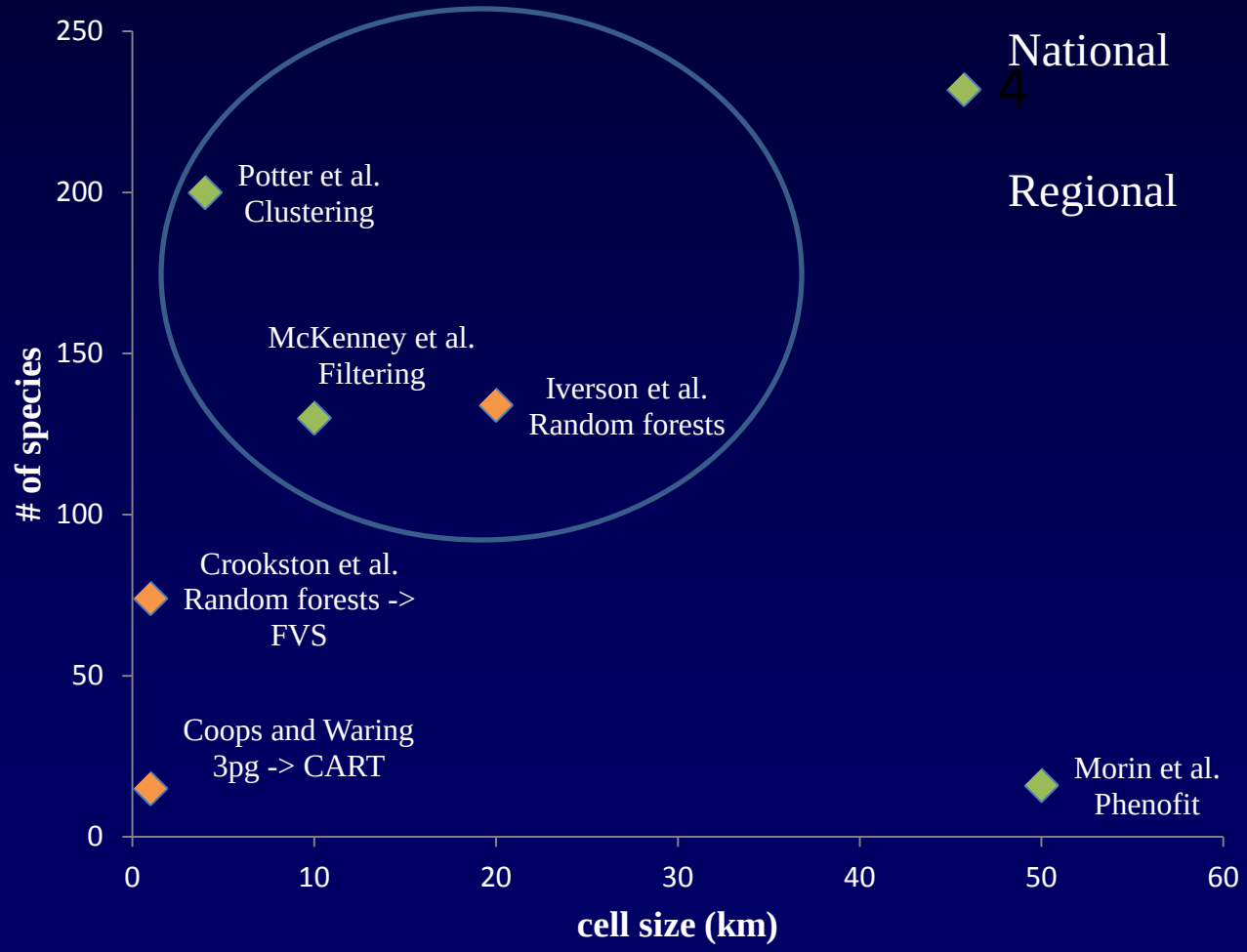
- **Fine filter**
  - Detailed modeling of **high priority species** or ecological system types within management units. Candidate species include Fraser Fir (*Abies fraseri), Red Spruce (Picea rubens), and Eastern Hemlock (Tsuga canadensis).*

- Both levels will include an assessment of uncertainty from multiple sources including climate envelope modeling algorithms, general circulation models, vegetation traits, and sampling.

Existing Vegetation Modeling Efforts



Existing Vegetation Modeling Efforts



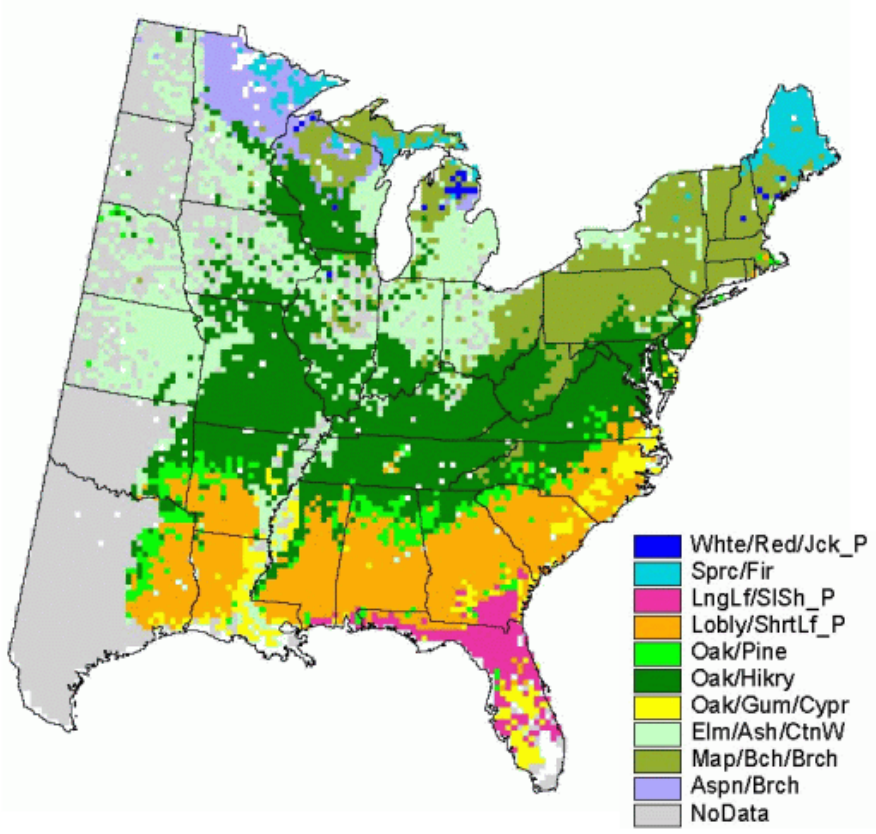
otential Future Forest Type Changes

he links below allow comparison of maps of potential forest-type changes ccording to the various GCM scenarios.
MPORTANT: Make sure you read the help file before interpreting the hanges.

View Summary of Changes

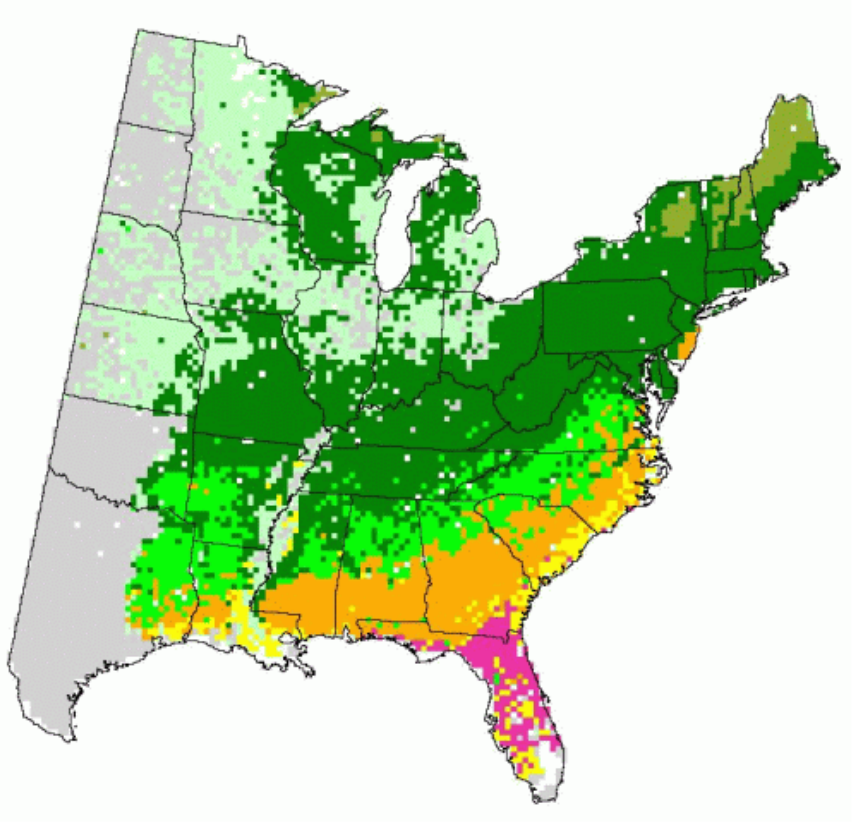
Climate Scenario Menu
Choose Forest Type from Menu

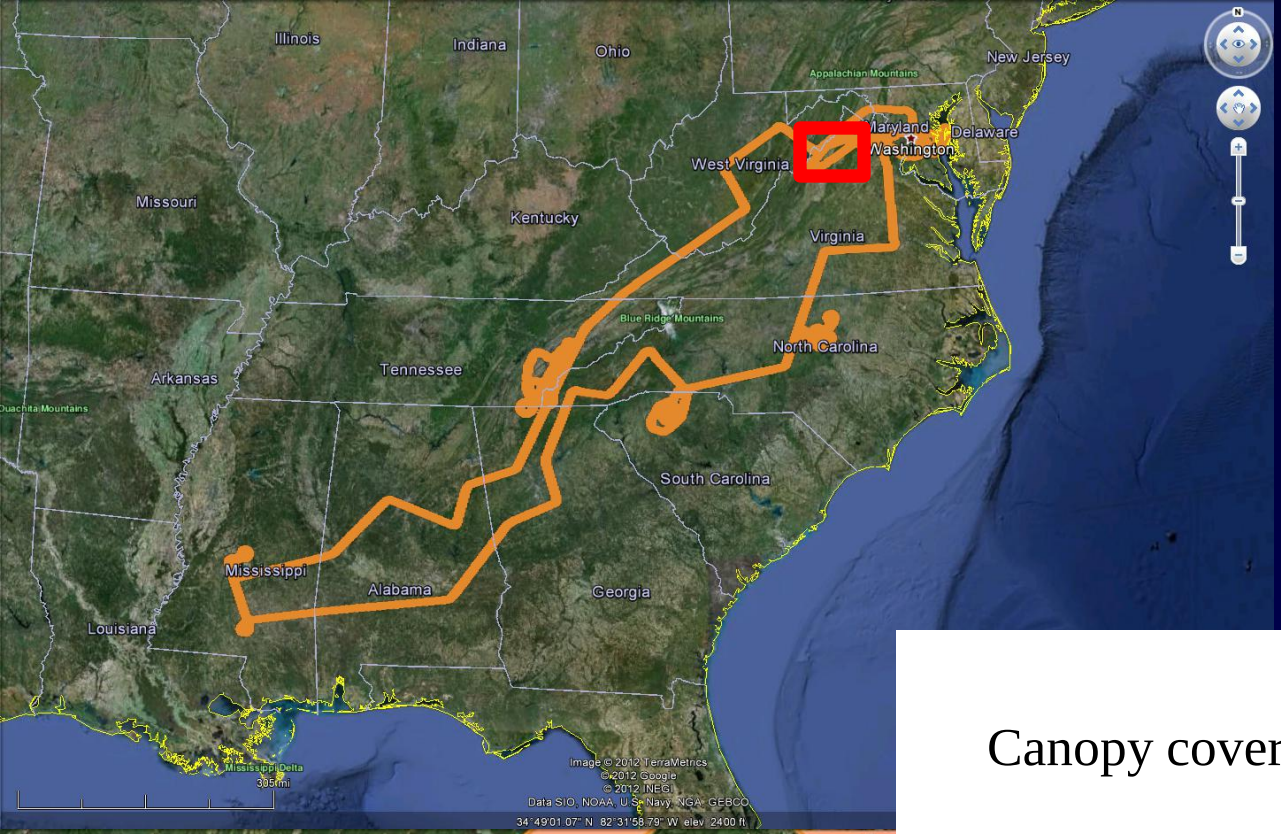
Current Modelled



Climate Scenario Menu
Choose Forest Type from Menu

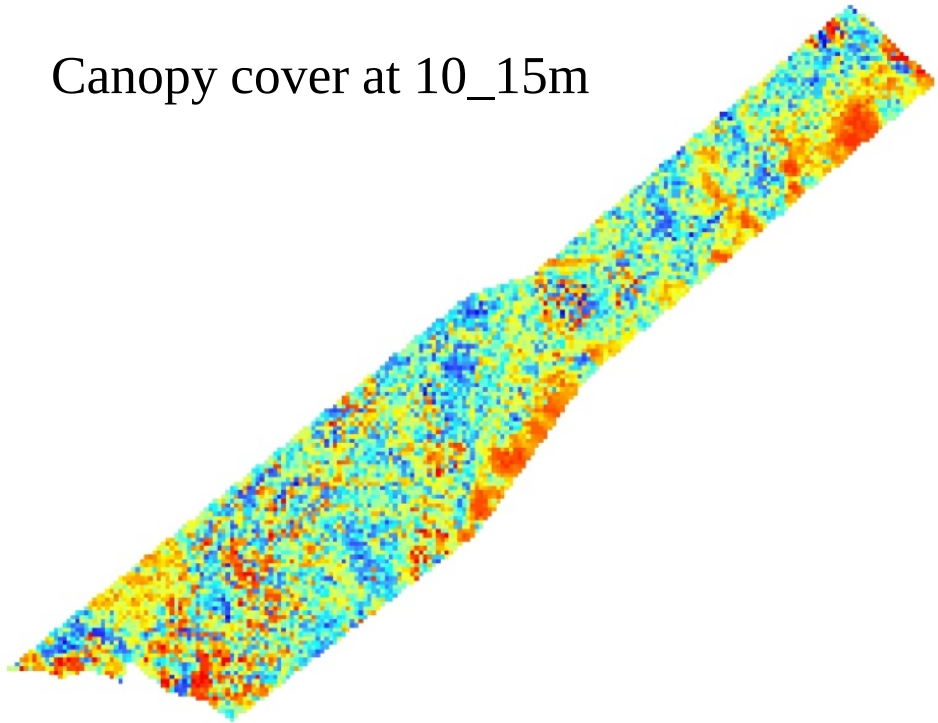
Avg. of 3 GCMs - High

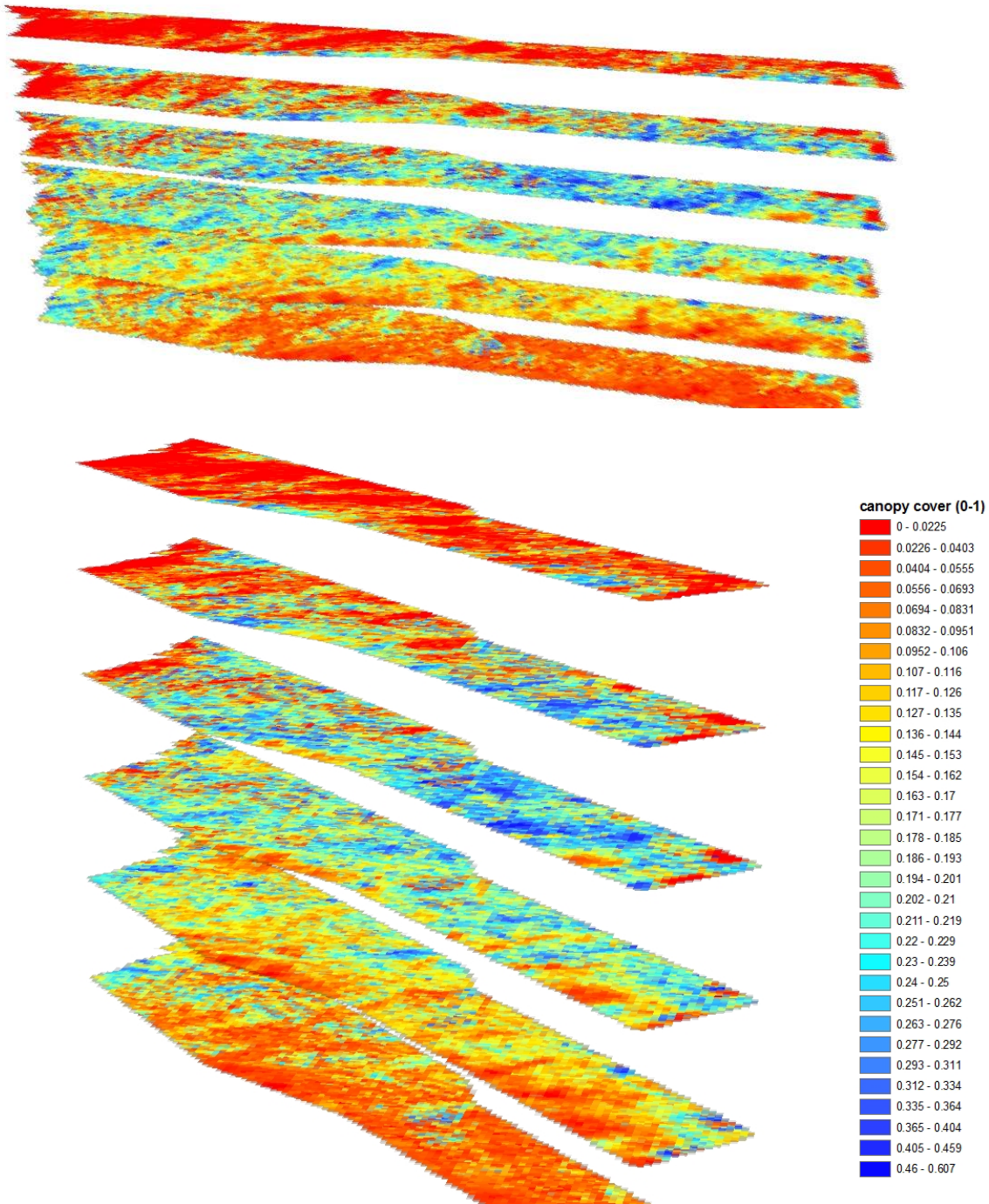




Vegetation Structure
- derivation of cover at multiple canopy heights / layers

Canopy cover at 10_15m





Canopy cover at

25-30m
20-25m
15-20m
10-15m
5-10m
0-5m

ALCC Science Needs

- Ecological flows
- Aquatic habitats
- Terrestrial landscapes
- Energy extraction
- Rare endemics
- Climate change

ALCC Science Needs

- **Terrestrial Landscapes**

- **Thematic Area Goal:**

  Assemble the necessary information or conduct studies necessary to develop and implement comprehensive regional strategies to conserve and manage forest/working forest communities across jurisdictions by inventorying significant regional forest communities, evaluating the condition, importance, and regional threats impacting these communities.

- **Specific Science Support Need**:

  Understanding representative/priority/focal species and population distributions across the region, their habitat relationships, and effective movement/dispersal linkages.

ALCC Science Needs

Terrestrial Landscapes cont.

- National and regional maps “are often at a resolution too coarse or a precision too inaccurate to be utilized at the scale of on-the-ground habitat conservation delivery”
- “need mapping products with units developed at a resolution necessary to take into account or respond predictably to successional dynamics and disturbance regimes”
- Need for products that “identify habitat structural characteristics (e.g., canopy cover, layer stratification)” which “are critical to better understanding habitat condition and determining suitability for specific species”

ALCC Science Needs

- **Climate Change**

- **Thematic Area Goal:**

  Work with partners and stakeholders to determine climate change adaptation and mitigation strategies that can be implemented and coordinated across multiple scales by applying the best available projections of how the regional climate will change and estimates of the impacts those changes will have on the region's natural and cultural resources.

- **Specific Science Support Need:**

  Support multi-scale vulnerability assessments that incorporate species-specific physiological data to identify habitats and species that would be most vulnerable to climate change in the LCC, especially range-limited/endemic species.