DEVELOPING ADAPTIVE SILVICULTURAL STRATEGIES IN THE CONTEXT OF CLIMATE CHANGE

Forestry & Natural Resources Webinar Portal
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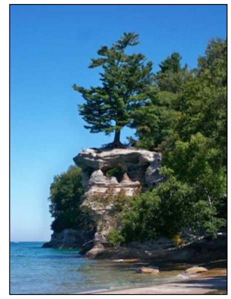
Roadmap ~ Climate Change Silviculture



Pictured Rocks National Lakeshore, MI

- Climate change overview
- Role of terrestrial ecosystems
- What can we do as forest managers?
  - Complexity
  - DFCs
- Adaptive silviculture planning
- Next steps: Adaptive Silviculture for Climate Change Project

CLIMATE CHANGE

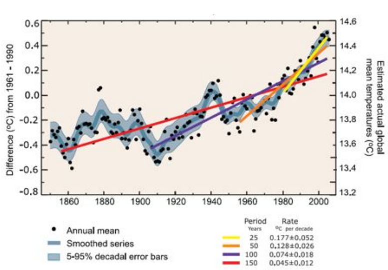
Polling Question:

Which answer best describes your belief in and concern about global warming?

A. Alarmed
B. Concerned
C. Cautious
D. Doubtful
E. Dismissive

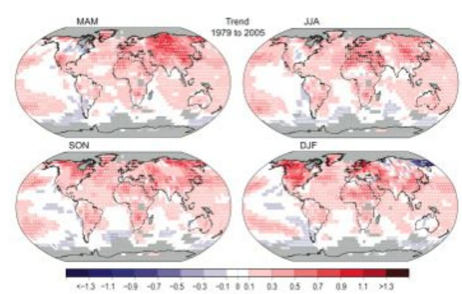
Climate Change… warming trend

- The average global surface temperature has risen 1.4°F over the past 100 years



IPCC 2007

Climate Change… warming trend



IPCC 2007

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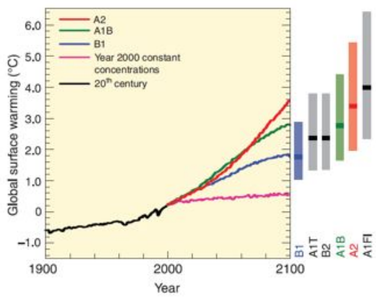
Uncertainty… Emissions



IPCC 2007

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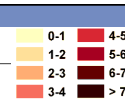
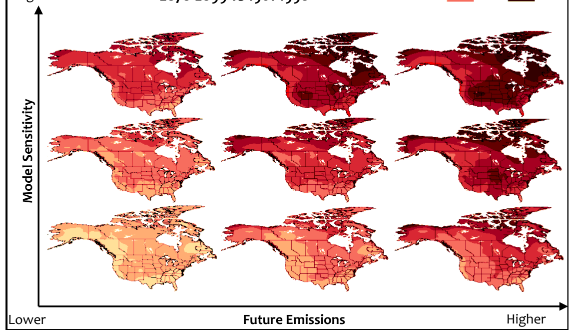
Consider a range of future conditions



Change in Mean Monthly Temperature (°C)
2070-2099 vs 1961-1990

Higher



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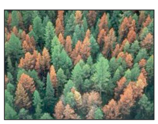
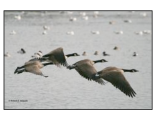
Why does climate change matter?

20-45 days shorter



Stress

Disturbance



Arrives 29 days earlier

More Stress

More disturbance

ROLE OF TERRESTRIAL ECOSYSTEMS

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Benefits of Climate Change

Increased productivity through…

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Benefits of Climate Change

Increased productivity through…

- Longer growing seasons
  - Evidence of phenological shifts (Parmesan and Yohe 2003)

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Benefits of Climate Change

Increased productivity through…

- Longer growing seasons
  - Evidence of phenological shifts (Parmesan and Yohe 2003)
- Increased precipitation in some regions
  - Wet areas have gotten wetter, dry areas drier (Dore 2005, IPCC 2007)

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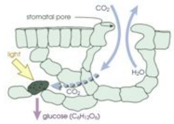
Benefits of Climate Change



Increased productivity through…

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- Increased precipitation in some regions
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- CO_2 fertilization (Ainsworth and Long 2005, Jones et al 2005, Norby et al 2005, Ainsworth and Rogers 2007)
  - Increased photosynthesis, increased water use efficiency

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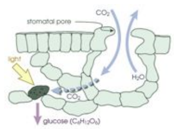
Benefits of Climate Change



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- CO_2 fertilization (Ainsworth and Long 2005, Jones et al 2005, Norby et al 2005, Ainsworth and Rogers 2007)
  - Increased photosynthesis, increased water use efficiency
- Increased foraging and voltinism
  - Minimum temps increasing 2x rate of maximum
  - Positive effects on species such as Karner Blue Butterfly (Haack 1993, Walther et al 2002, Altermatt 201)

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Increased Stresses

- Acclimation to CO_2 fertilization
  - Varies by species and site
  - Nutrient deficiencies (especially N)
  - Limited sink strength
  - Sensitive to ozone pollution (+/-)
  - Evidence increased NPP and biomass, but limited evidence of long-term sequestration
    - Old trees
    - Wood growth and soil carbon – varies

The fertilization effect may be transitory, photosynthesis may not stay elevated, ecosystem carbon may not increase

Oren et al 2001, Ainsworth and Long 2005, Jones et al 2005, Norby et al 2005, Ainsworth and Rogers 2007

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Increased Stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
  - Wind storms and hurricanes
  - Ice storms
  - Heat waves and droughts
  - Heavy precipitation
  - "Events" are not well modeled

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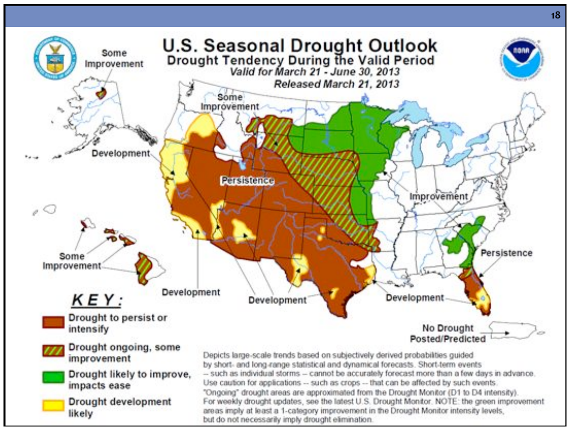


Increased Stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
  - Altered timing of aquifer recharge
  - Potential declines in summer seasonal stream flow
  - Potential increases in flashiness and episodic high flows
  - Increased water stress in late summer
  - Phenological shifts and asynchrony

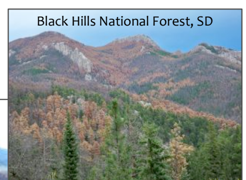
Dale et al 2001, Huntingon 2004, Parmesan 2006, Cherkauer and Sinha 2010

Increased Stresses

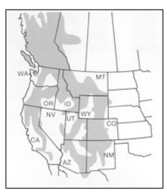
- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
  - Pests migrating northward
  - Accelerated lifecycles
  - Decreased probability of lower lethal temperatures
  - Increased winter minimum temps → potential range expansion (hemlock wooly adelgid, MPB)

Ayres and Lombardero 2000, Woods et al 2005, Parmesan 2006, Soja et al 2006

Mountain pine beetle – caused mortality



Helena National Forest, MT http://www.fs.fed.us/ccrc/



Increased Stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
  - Early bud break and loss of cold hardening
  - Frost damage during spring freezing
  - Less insulation in cold snaps

Ayres and Lombardero 2000, Hennon et al 2006

Increased Stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
- Increased frequency and intensity of fire

Increased frequency and intensity of wildfire

Duck Lake Fire, MI
May 2013

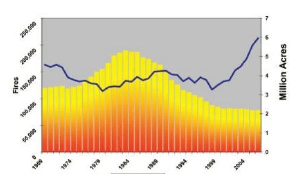


Figure 5-1. Ten-year averages of acres burned and number of fires (Source: Compiled from National Interagency Fire Center 2007).

SAF 2008

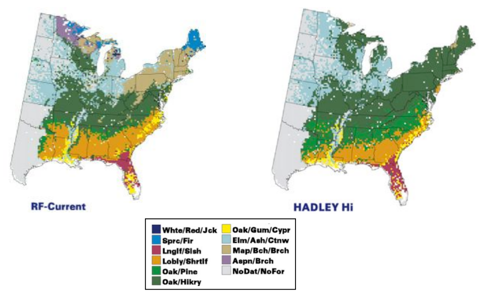
Increased Stresses

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
- Increased frequency and intensity of fire
- Species range shifts

Species Range Shifts

Tree Atlas

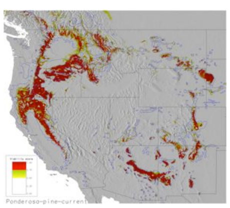
Climate induced changes in biophysical conditions will likely lead to shifts in species range distributions



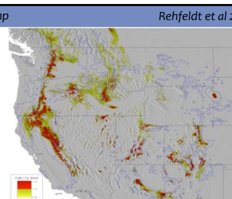
Iverson et al 2008

Pinus ponderosa

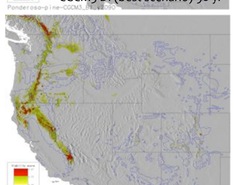
Plant Species and Climate Profile Predictions



Current species distribution



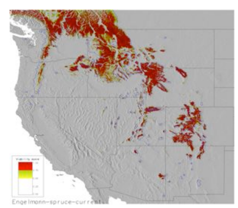
CGCM3 B1 (best scenario) 90 yr



HADCM3 A2 (worst scenario) 90 yr

Picea engelmannii

Plant Species and Climate Profile Predictions



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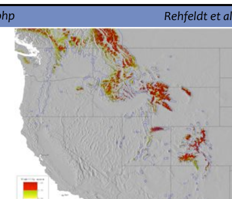

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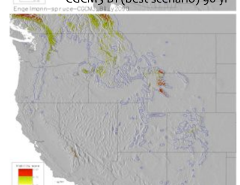
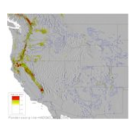


HADCM3 A2 (worst scenario) 90 yr

Increased Stresses

- Species range shifts:
  - Range shifts ≠ instant catastrophic dieback
  - Mature trees should fare better
    - Developed root system
    - Greater carbohydrate reserves
  - Stress factors will increase in severity
    - Temperature
    - Moisture
    - Competition
  - Increased susceptibility to disturbance

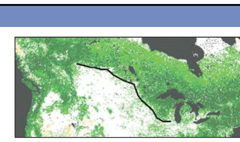


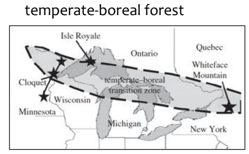
Dale et al 2001, Iverson et al 2008

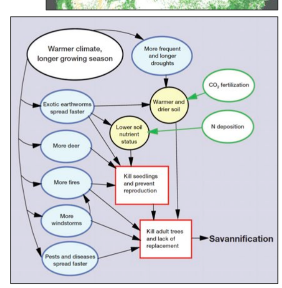
Complex Interactions

- *Savannification*
- Northeastward shift in the prairie-forest border

- Trophic cascades, invasive species, and body-size hierarchies interactively modulate climate change response of ecotonal temperate-boreal forest







Frelich & Reich 2010; Frelich et al 2012

Key vulnerabilities ~ Midwest Region

- Risk will be greater in low diversity systems
- Disturbance will destabilize static ecosystems
- Greater problems for species already in decline
- Resilience may be weakened in fragmented ecosystems
- Further reductions in habitat will impact threatened, endangered, and rare species
- Ecosystem changes will have significant effects on wildlife
- Impaired ability of forested watersheds to produce reliable supplies of clean water
- Recreation within forested ecosystems may change in extent and timing
- Altered traditional and modern cultural connections to forests

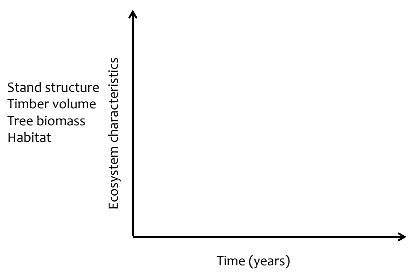
Swanston et al 2011, Handler et al 2012

Accommodating change

- **Diversity** (**complexity**) will be the key to maintaining ecosystem function, even if the species mixture of the system changes
  - Species that are currently increasing
  - Species with wider ecological range of tolerances
  - Species with greater genetic diversity
  - Species and ecosystems adapted to disturbances
  - Species and ecosystems adapted to warmer, drier climates
  - Ecosystems with diverse communities and species
  - Ecosystems contained within larger, contiguous blocks

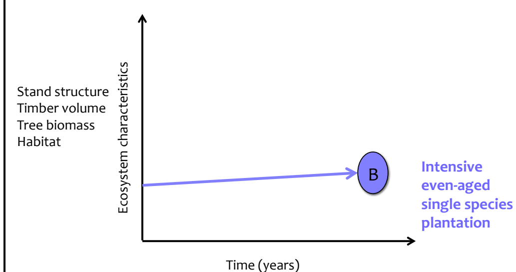
Swanston et al 2011

Silviculture systems



Following Puettmann et al 2009

Silviculture systems



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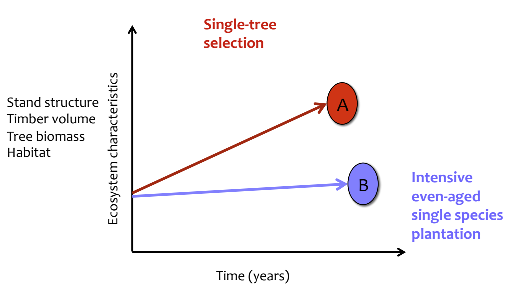

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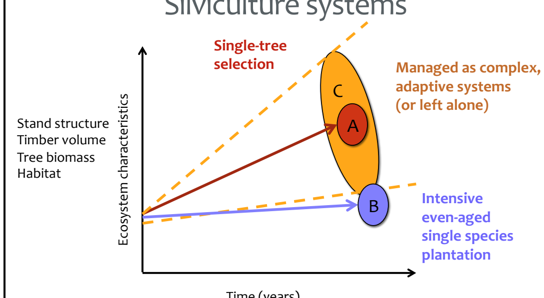

Following Puettmann et al 2009

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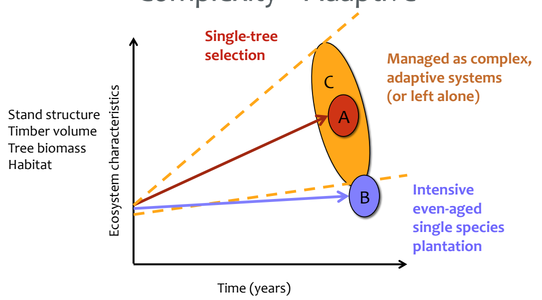
Complexity ≈ Adaptive



Managing for complexity allows forests to be "creative" in adapting to new altered conditions

Following Puettmann et al 2009

WHAT CAN WE DO AS FOREST MANAGERS?

What can be done during the course of active management on public and private lands that would increase the resistance and resilience of forest stands within the context of climate change?

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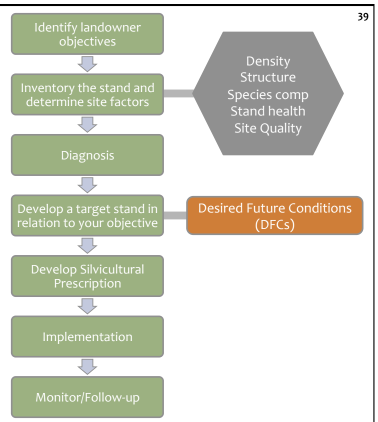
The Silviculture Prescription Process



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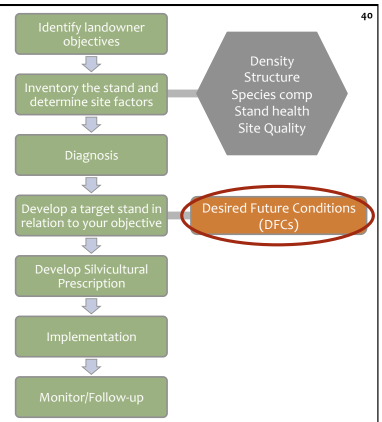

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Desired Future Condition (DFC)

- **DFC** = a description of the land or resource conditions that are believed necessary if goals and objectives are fully achieved
  - SAF Dictionary of Forestry, 1998

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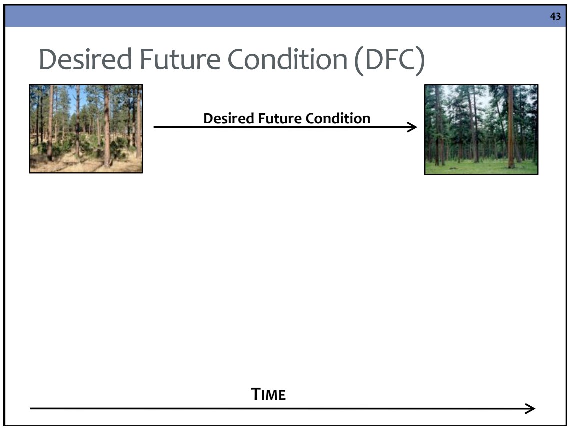
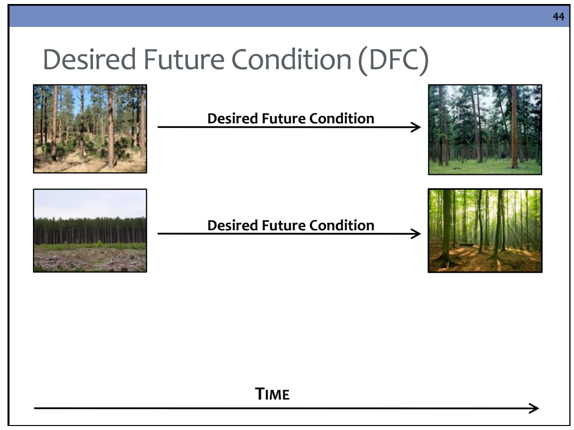
Polling Question:

When managing forests in my region, desired [future] conditions are often defined by some type of historic structure and/or species composition.

A. True
B. False
C. I'm seeing this approach change…


43
Desired Future Condition (DFC)
Desired Future Condition
TIME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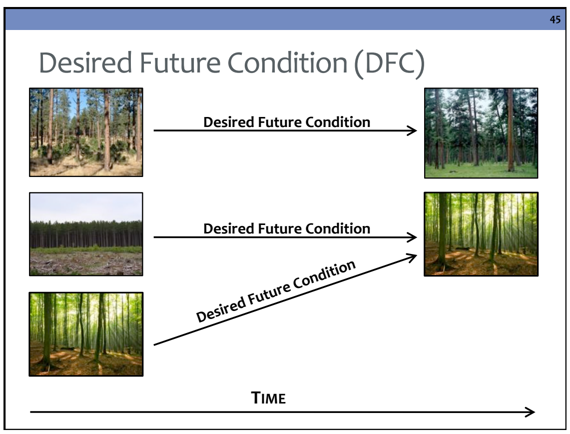
TIME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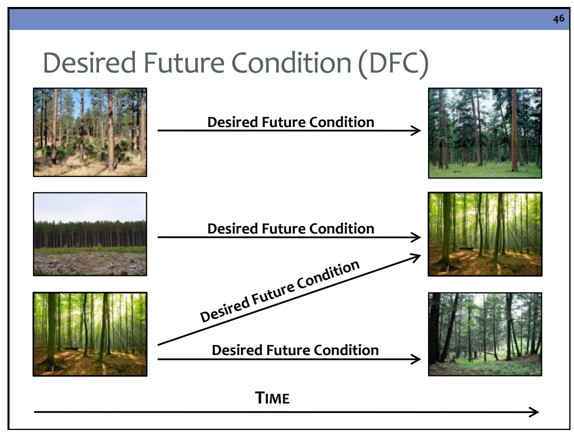
Desired Future Condition (DFC)
Desired Future Condition
Desired Future Condition
Desired Future Condition
TIME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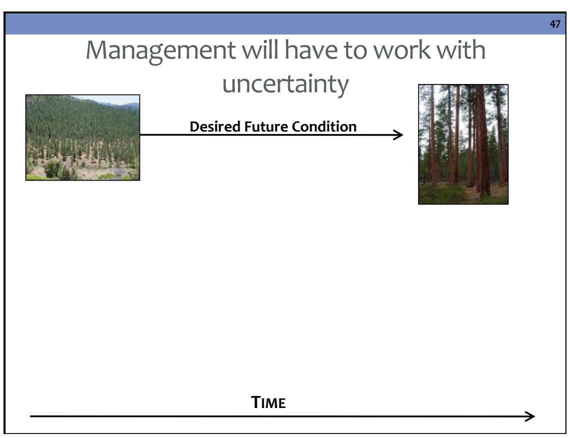
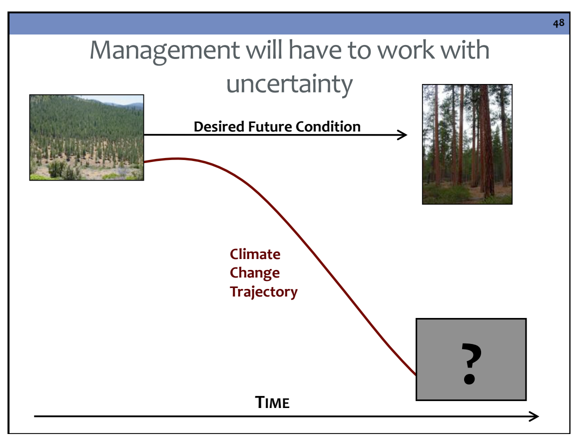
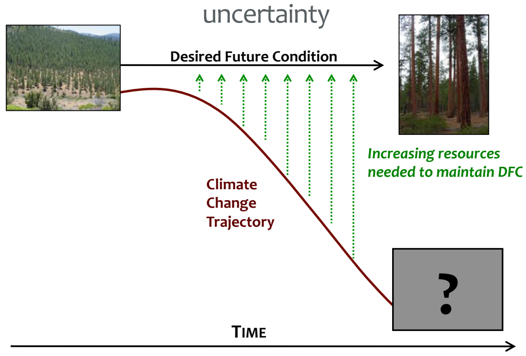
Desired Future Condition (DFC)
Desired Future Condition
Desired Future Condition
Desired Future Condition
Desired Future Condition
TIME


47
Management will have to work with uncertainty
Desired Future Condition
TIME


48
Management will have to work with uncertainty
Desired Future Condition
Climate
Change
Trajectory
?
TIME

Management will have to work with uncertainty



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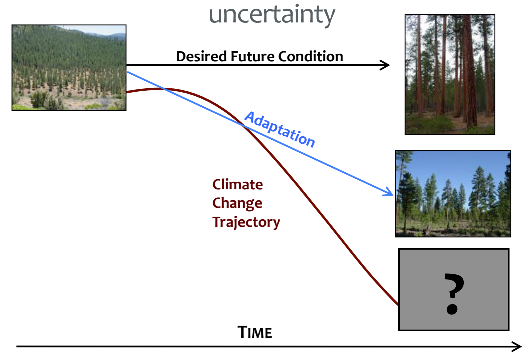
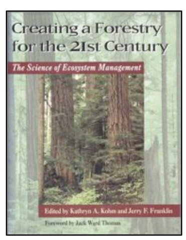


Desired Future Condition (DFC)

- The concept of "Desired Future Conditions" should be replaced with "Desired Future Dynamics"
  - Kohm and Franklin 1997
- Refocus on *desired future dynamic processes* rather than static goals of composition and structure



Resource Management and Climate Change

ADAPTATION
- Actions to moderate the vulnerability of forests to climate change
- Position forests to become more healthy, resistant, & resilient
- Facilitate ecosystem responses to climate change when appropriate

MITIGATION
- Use of forests to sequester carbon, provide renewable energy from biomass, & avoid carbon losses from fire, mortality, conversion, etc.

Climate Change = Adaptive Silviculture

- **RESISTANCE** – improve the defenses of the forest against effects of change
  - Short-term
  - High-value

Millar et al 2007, 2008

Climate Change = Adaptive Silviculture

- **RESISTANCE** – improve the defenses of the forest against effects of change
- **RESILIENCE** – accommodate gradual change, usually returning to a prior condition after disturbance
  - Thinning stands to improve health and vigor
  - Manage vegetation following disturbance

Millar et al 2007, 2008

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Climate Change = Adaptive Silviculture

- **RESISTANCE** – improve the defenses of the forest against effects of change
- **RESILIENCE** – accommodate gradual change, usually returning to a prior condition after disturbance
- **RESPONSE** – intentionally accommodate change, enabling ecosystems to adaptively respond
  - Assist transitions and range shifts
  - Increase connectivity for migration corridors

Millar et al 2007, 2008

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- **REALIGNMENT** – move heavily disturbed systems into alignment with current and future conditions rather than restoring to a historical baseline

Millar et al 2007, 2008

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Silvicultural Opportunities

Millar et al 2007, 2008

ADAPTIVE SILVICULTURE PLANNING

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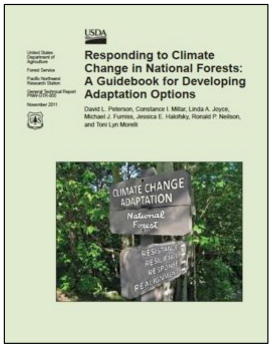
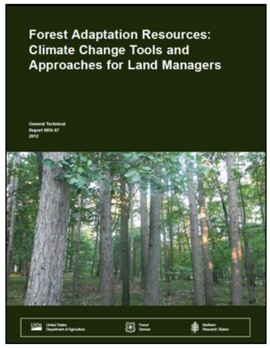
Polling Question:

How does climate change rate as a factor in natural resource management and planning in your region?

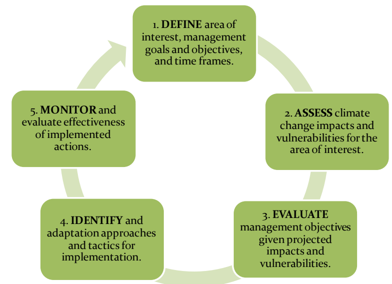
A. Priority
B. One of many important considerations
C. Minor consideration
D. Not a consideration





Forest Adaptation Resources:

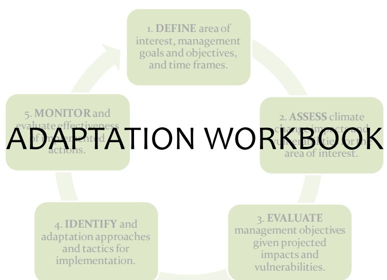
Climate Change Tools and Approaches for Land Managers



Swanston and Janowiak 2012

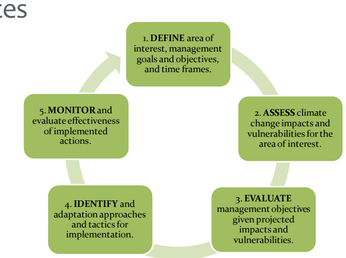
Forest Adaptation Resources:

Climate Change Tools and Approaches for Land Managers



Swanston and Janowiak 2012

Forest Adaptation Resources

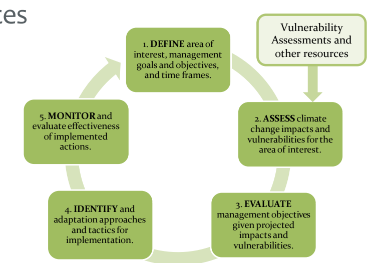


Swanston and Janowiak 2012

1. Define area of interest

- Northern hardwood stand dominated by sugar maple in the eastern Upper Peninsula of Michigan
- Minor component of:
  - Yellow birch
  - Eastern hemlock
  - American basswood
  - Eastern white pine

Forest Adaptation Resources



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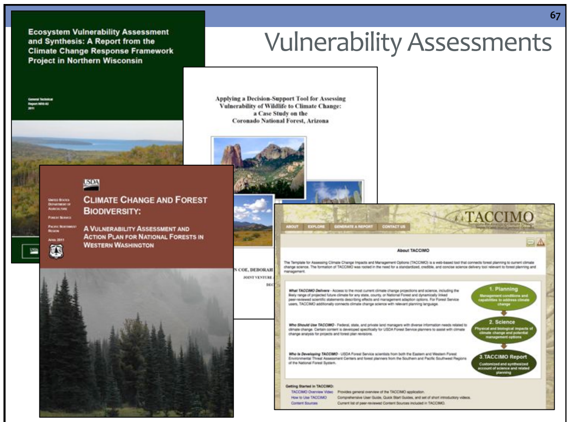
Vulnerability Assessments



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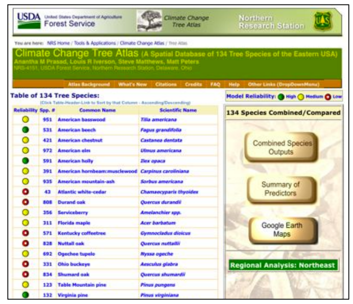
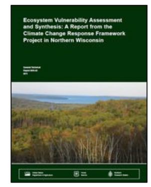
2. Assess climate change impacts and vulnerabilities





http://www.nrs.fs.fed.us/atlas/tree/

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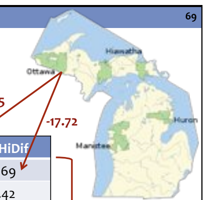
Mean IV change from current Hiawatha National Forest

LOSERS



	Species	Current	HadHiDif
*	Sugar maple	12.21	-7.69
	Northern white cedar	8.99	-7.42
	Balsam fir	8.25	-7.27
	Quaking aspen	7.03	-6.39
	Red maple	10.43	-4.34
	Jack pine	5.15	-4.17
	Red pine	3.50	-2.76
*	Yellow birch	2.05	-1.72
*	Eastern hemlock	2.45	-1.68
*	Eastern white pine	2.69	-0.73

Top 5 losers

http://www.nrs.fs.fed.us/atlas/tree/

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Mean IV change from current Hiawatha National Forest

WINNERS

	Species	Current	HadHiDif
	White oak	0.02	6.06
	Eastern redcedar	0.00	4.65
	Black oak	0.02	4.54
	Silver maple	0.00	3.98
	Post oak	0.00	3.16
*	Northern red oak	1.19	3.04
	American elm	0.84	2.65
	Eastern cottonwood	0.02	2.34
*	White ash	1.18	2.07
	Hackberry	0.00	2.06

Top 10 winners

http://www.nrs.fs.fed.us/atlas/tree/

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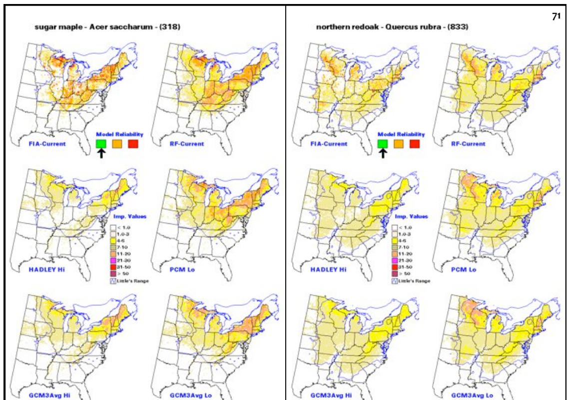

http://www.nrs.fs.fed.us/atlas/tree/

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2. Assess climate change impacts and vulnerabilities

- Warmer temperatures
- Altered precipitation regimes
- Increased potential for drought
- Many species expected to fare worse in the future
  - Sugar maple, yellow birch, eastern hemlock, eastern white pine
- Increases in pests and disease
  - Emerald ash borer, sugar maple decline, other…

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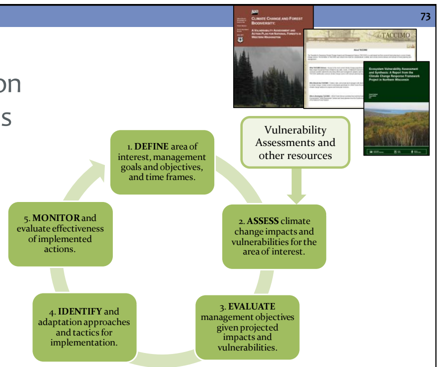
Forest
Adaptation
Resources



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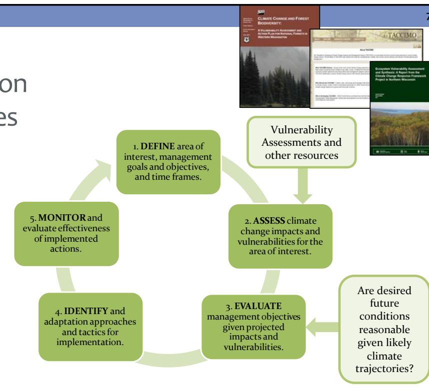
Forest
Adaptation
Resources



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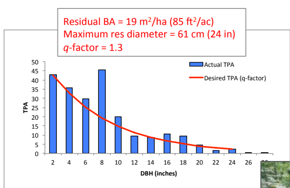
Uneven-aged northern hardwoods management



Individual tree selection in northern hardwoods dominated by sugar maple (*Acer saccharum*) homogenizes species composition

"Maplization"
"Acerification"

Long-term individual tree selection = homogenization

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3. Evaluate management objectives given impacts and vulnerabilities

- Historic management objective: high-quality sugar maple sawtimber
- Silviculture approach: uneven-aged, balanced age structure by a q-factor, short cutting cycle length

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3. Evaluate management objectives given impacts and vulnerabilities

- Historic management objective: high-quality sugar maple sawtimber
- Silviculture approach: uneven-aged, balanced age structure by a q-factor, short cutting cycle length

- Contemporary management objective: increase resiliency, promote species diversity and complexity
- Silviculture approach: alternative methods that promote regeneration of midtolerants and species that are expected to fare better in a future climate

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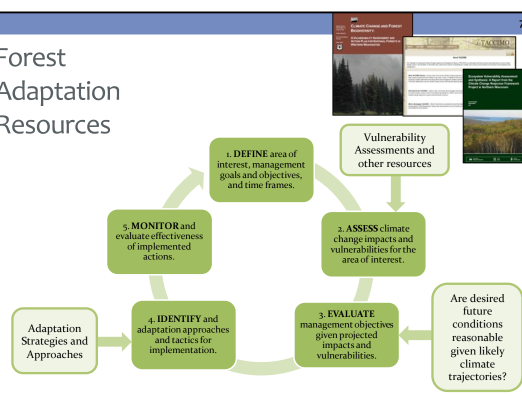
Forest
Adaptation
Resources



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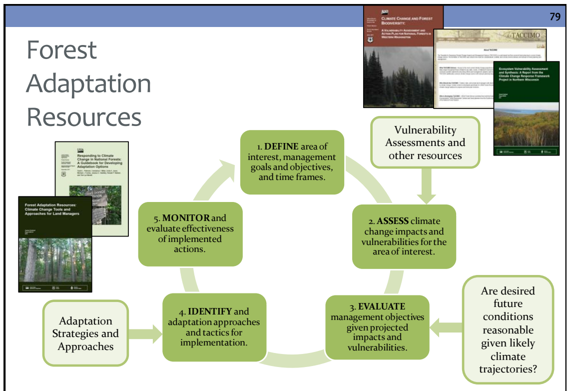
Forest Adaptation Resources



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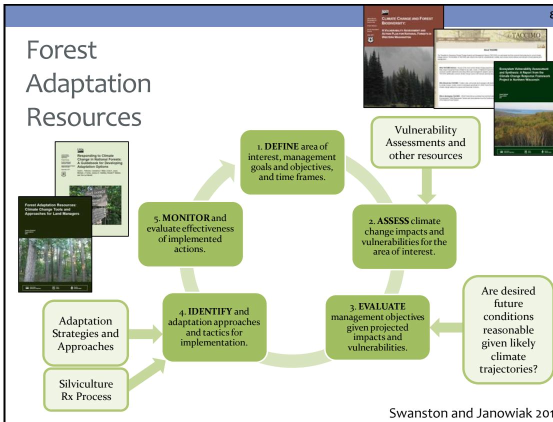
Forest Adaptation Resources



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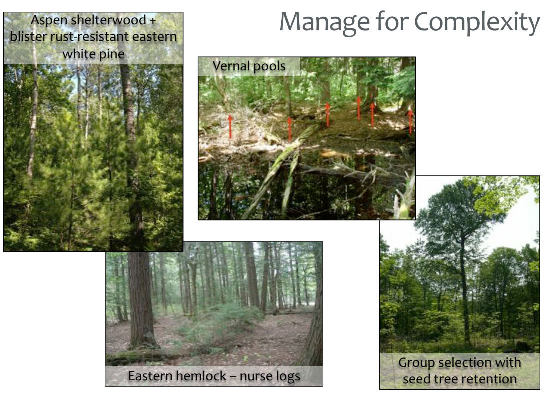
Manage for Complexity



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4. Identify adaptation approaches and tactics for implementation

- Business as usual isn't going to work
- Enhance and maintain species and structural diversity in northern hardwoods
  - Create CWD
  - Yellow birch seed-tree + group selection
  - Protect vernal pools
  - Femelschlag
  - Rethink shelterwoods
  - Use appropriate planting stock
  - Think creatively

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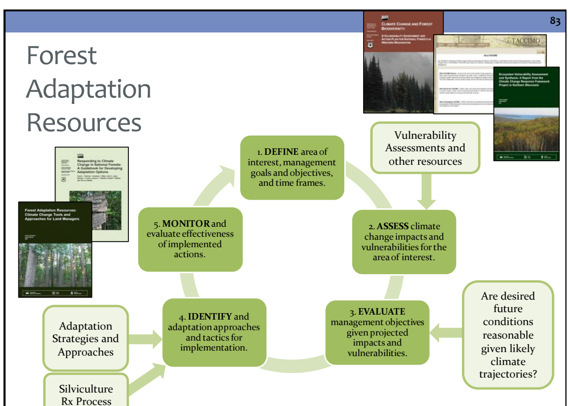
Forest Adaptation Resources



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NEXT STEPS

Adaptive Silviculture for Climate Change

…a project with a national scope

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Adaptive Silviculture for Climate Change (ASCC)

- Forest managers need robust examples of how to integrate climate change adaptation into silvicultural planning and on-the-ground actions
- Core Team:
  - Linda Nagel – Lead University PI, MTU, NIACS
  - Jim Guldin – Lead Forest Service PI, SRS
  - Matt Powers – ASCC Project Coordinator, MTU, NIACS
  - Chris Swanston – Research Ecologist, NRS, NIACS
  - Maria Janowiak – Scientist, NRS, NIACS

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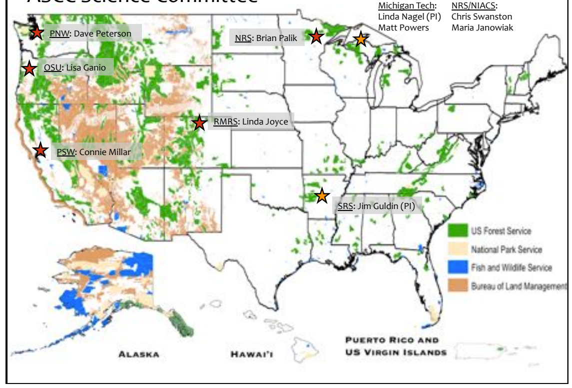
ASCC Science Committee



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Adaptive Silviculture for Climate Change (ASCC)

PROJECT GOALS (1)

- Populate a multi-region study design with ecosystem-specific climate change adaptation treatments using input from an expert panel of regional scientists and local managers
  - Primary objectives: compare key variables among various climate change adaptation treatments in 3-5 different forest types across the United States
    - Forest growth and productivity
    - Overstory and understory species composition
    - Forest health and/or tree vigor

Treatments
Resistance
Resilience
Transition
No Action
Sensu Millar et al 2007

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Adaptive Silviculture for Climate Change (ASCC)

PROJECT GOALS (2)

- Introduce natural resource managers to conceptual tools and approaches that help integrate climate change into natural resource management and silvicultural decision making
  - Primary objectives: conduct training sessions at participating Forests for an audience of local managers and scientists
    - Discuss projected climate change impacts and vulnerabilities relevant to local management goals
    - Introduce conceptual tools that help managers identify appropriate adaptation approaches and tactics

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Summary… Climate Change

- Future change is uncertain in severity, but certainly coming
- Impacts of the changing climate on forests
  - Same old stresses, but worse
- Severity is affected by local conditions
- Business as usual isn't going to cut it
- We need to incorporate climate change into natural resource management

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Summary… Adaptive Silviculture

- The adaptive planning process:
  - Helps us understand trends related to the changing climate
  - Translate this information into tactics that can be implemented on the ground
- Defining management goals and objectives based on a range of future conditions will be more practical than using historic benchmarks alone, especially in the context of "restoration"
- Managing for complexity may increase resilience
- Adaptive management will help us attain the ultimate goal of sustaining ecosystem function


Thanks!