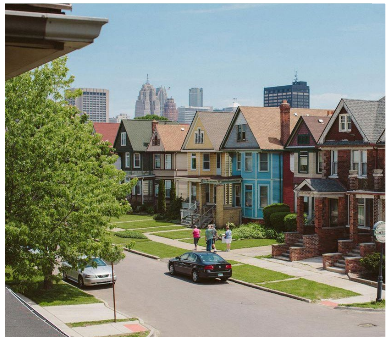
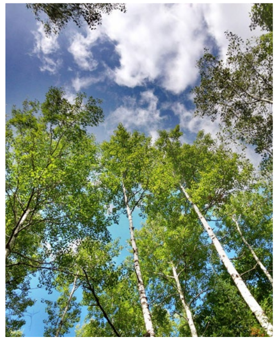
What Does Adaptive Silviculture Look Like?

Yale Climate-Smart Forestry Series
September 25, 2023





USDA

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

NIACS Northern Institute of Applied Climate Science

Maria Janowiak, USDA Forest Service
Linda Nagel, Utah State University
Courtney Peterson, Colorado State University
and many, many colleagues and collaborators!

Silviculture

Silviculture is the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society such as wildlife habitat, timber, water resources, restoration, and recreation on a sustainable basis. (US Forest Service)

Tools in the toolbox:
- Thinning, harvest
- Planting
- Prescribed fire
- Site preparation
- Etc.

With changing conditions, tools may need to be used in novel ways.

Today's Topics

- Frameworks for climate change adaptation
- Adaptive Silviculture for Climate Change (ASCC) Network of experimental silviculture trials
- Case studies from ASCC

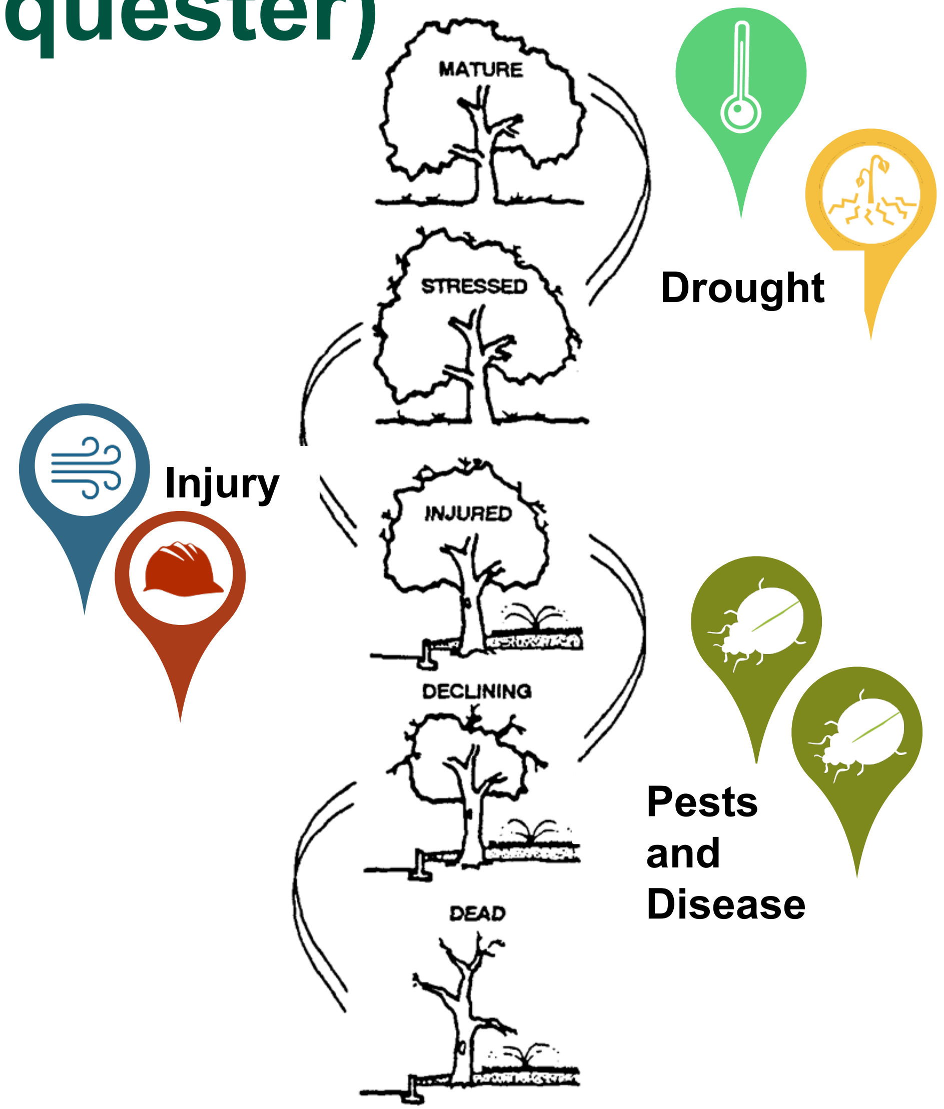
Forests in a Time of Rapid Change

- Forests provide essential ecosystem services, including spiritual and material benefits
- Global change is creating increasingly dynamic, uncertain futures
- Contemporary disturbances are often catastrophic events with frequent intervals and repeated occurrences
- Forest recovery may be decadal or longer
- Legacy of land use and fire suppression
- Changing societal expectations of forests
- ***Climate adaptation will be key to a sustainable future***

Photo: Colorado State Forest Service

A changing climate poses risks to forests (and the carbon they sequester)

- Altered climate
- Extreme weather
- Chronic stress
- Disturbances
- Insect pests
- Forest diseases
- Invasive species
- Altered habitat suitability



Drawing: Bartlett Tree Experts

Adaptive Forest Management

Forestry An International Journal of Forest Research — Institute of Chartered Foresters

Forestry 2021; 1–10, https://doi.org/10.1093/forestry/cpab047

The changing culture of silviculture

Alexis Achim[1,†,*], Guillaume Moreau[1,†], Nicholas C. Coops[2,†], Jodi N. Axelson[3], Julie Barrette[4], Steve Bédard[4], Kenneth E. Byrne[2,5], John Caspersen[6], Adam R. Dick[7], Loïc D'Orangeville[8], Guillaume Drolet[4], Bianca N.I. Eskelson[2], Cosmin N. Filipescu[9], Maude Flamand-Hubert[1], Tristan R.H. Goodbody[2], Verena C. Griess[10], Shannon M. Hagerman[2], Kevin Keys[11], Benoit Lafleur[12], Miguel Montoro Girona[12,13], Dave M. Morris[14], Charles A. Nock[15], Bradley D. Pinno[15], Patricia Raymond[4], Vincent Roy[16], Robert Schneider[17], Michel Soucy[18], Bruce Stewart[11], Jean-Daniel Sylvain[4], Anthony R. Taylor[8,19], Evelyne Thiffault[1], Nelson Thiffault[16], Udaya Vepakomma[20] and Joanne C. White[21]

NRC Research Press — CONCEPT PAPER

Building on the last "new" thing: exploring the compatibility of ecological and adaptation silviculture[1]

Anthony W. D'Amato and Brian J. Palik

DISCUSSION — Open Access

The functional complex network approach to foster forest resilience to global changes

Check for updates

Christian Messier[1,2*], Jürgen Bauhus[3], Frederik Doyon[1], Fanny Maure[2], Rita Sousa-Silva[1], Philippe Nolet[1], Marco Mina[2,4], Núria Aquilué[2], Marie-Josée Fortin[5] and Klaus Puettmann[6]

forests — MDPI

Communication

SilvAdapt.Net: A Site-Based Network of Adaptive Forest Management Related to Climate Change in Spain

Antonio J. Molina [1,*,†], Rafael M. Navarro-Cerrillo [2,†], Javier Pérez-Romero [1], Reyes Alejano [3], Juan F. Bellot [4], Juan A. Blanco [5], Jesús J. Camarero [6], Arnaud Carrara [7], Víctor M. Castillo [8], Teresa Cervera [9], Gonzalo G. Barberá [8], María González-Sanchis [1], Álvaro Hernández [10], Juan B. Imbert [5], María N. Jiménez [11], Pilar Llorens [12], Manuel E. Lucas-Borja [13], Gerardo Moreno [14], Mariano Moreno-de las Heras [12,15,16], Francisco B. Navarro [17], Guillermo Palacios [2], Noemí Palero [9], María A. Ripoll [17], David Regües [6], Francisco J. Ruiz-Gómez [2], Alberto Vilagrosa [18] and Antonio D. del Campo [1,†]

Responding to Ecosystem Transformation: Resist, Accept, or Direct?

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Robert A. Newman | University of North Dakota, Department of Biology, Grand Forks, ND

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Frank J. Rahel | University of Wyoming, Department of Zoology and Physiology, Laramie, WY

Suresh A. Sethi | U.S. Geological Survey, New York Cooperative Fish and Wildlife Research Unit, Cornell University, Ithaca, NY

Jennifer L. Wilkening | U.S. Fish and Wildlife Service, Southern Nevada Fish and Wildlife Office, Las Vegas, NV

REVIEW

Climate-Smart Forestry: Promise and risks for forests, society, and climate

Lauren Cooper[1*], David MacFarlane[2]

PLOS CLIMATE

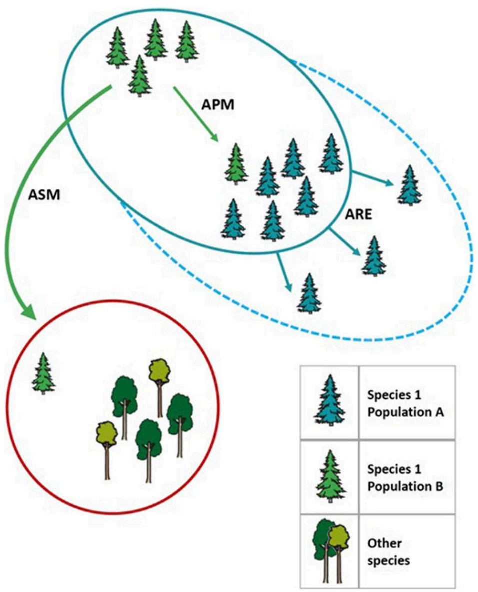
What is Climate-Smart Forestry? A definition from a multinational collaborative process focused on mountain regions of Europe

Euan Bowditch[a], Giovanni Santopuoli[b,c,*], Franz Binder[d], Miren del Río[e,f], Nicola La Porta[g,h], Tatiana Kluvankova[i], Jerzy Lesinski[j], Renzo Motta[k], Maciej Pach[l], Pietro Panzacchi[c,m], Hans Pretzsch[n], Christian Temperli[o], Giustino Tonon[m], Melanie Smith[a], Violeta Velikova[p], Andrew Weatherall[q], Roberto Tognetti[b,c,h]

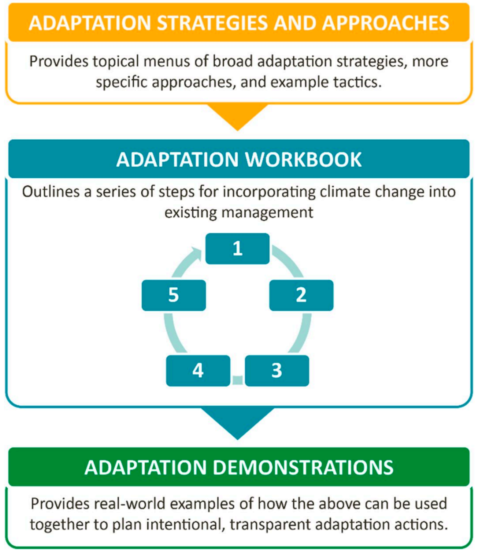
silviculture

Adaptive Silviculture for Climate Change: A National Experiment in Manager-Scientist Partnerships to Apply an Adaptation Framework

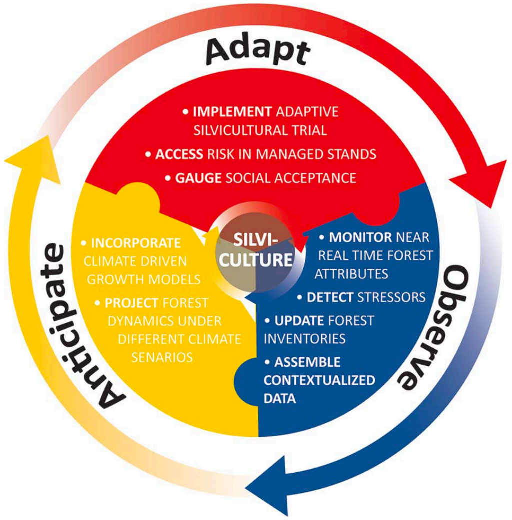
Linda M. Nagel, Brian J. Palik, Michael A. Battaglia, Anthony W. D'Amato, James M. Guldin, Christopher W. Swanston, Maria K. Janowiak, Matthew P. Powers, Linda A. Joyce, Constance I. Millar, David L. Peterson, Lisa M. Ganio, Chad Kirschbaum, and Molly R. Roske



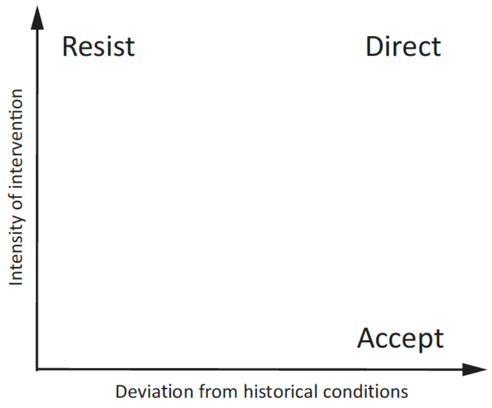
APM
ASM
ARE
Species 1 Population A
Species 1 Population B
Other species



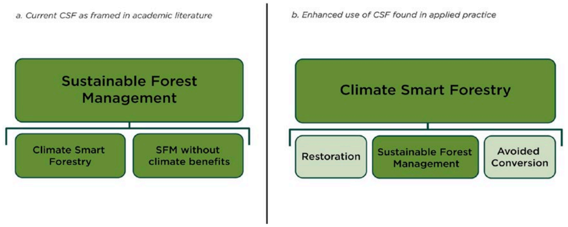
ADAPTATION STRATEGIES AND APPROACHES
Provides topical menus of broad adaptation strategies, more specific approaches, and example tactics.
ADAPTATION WORKBOOK
Outlines a series of steps for incorporating climate change into existing management
1
2
3
4
5
ADAPTATION DEMONSTRATIONS
Provides real-world examples of how the above can be used together to plan intentional, transparent adaptation actions.



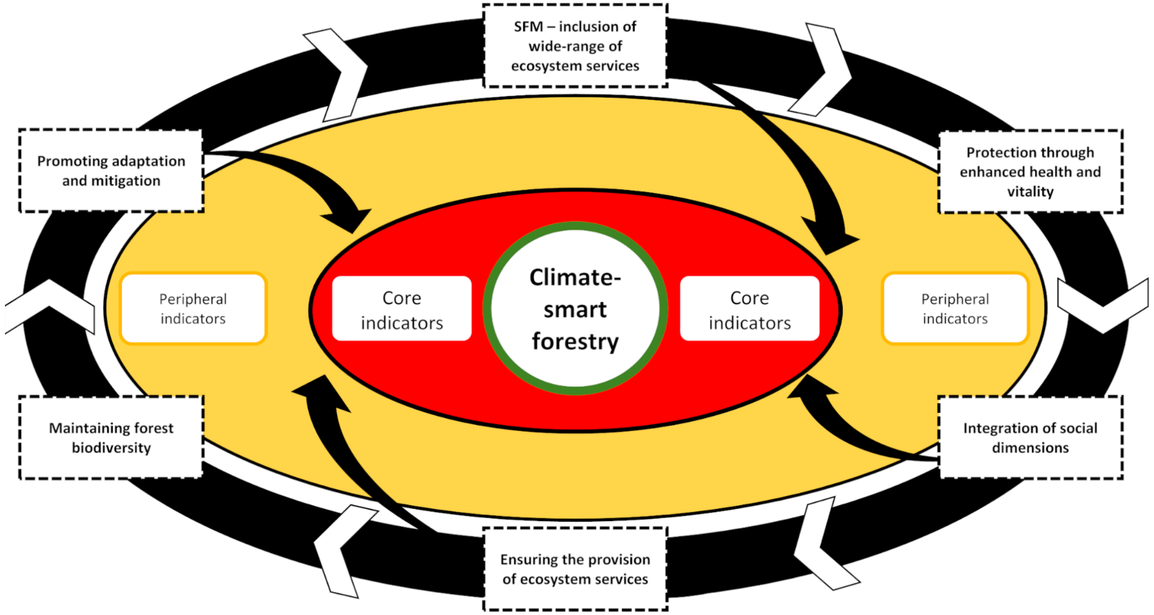
Adapt
• IMPLEMENT ADAPTIVE SILVICULTURAL TRIAL
• ACCESS RISK IN MANAGED STANDS
• GAUGE SOCIAL ACCEPTANCE
SILVI-CULTURE
• MONITOR NEAR REAL TIME FOREST ATTRIBUTES
• DETECT STRESSORS
• UPDATE FOREST INVENTORIES
• ASSEMBLE CONTEXTUALIZED DATA
Observe
• INCORPORATE CLIMATE DRIVEN GROWTH MODELS
• PROJECT FOREST DYNAMICS UNDER DIFFERENT CLIMATE SENARIOS
Anticipate



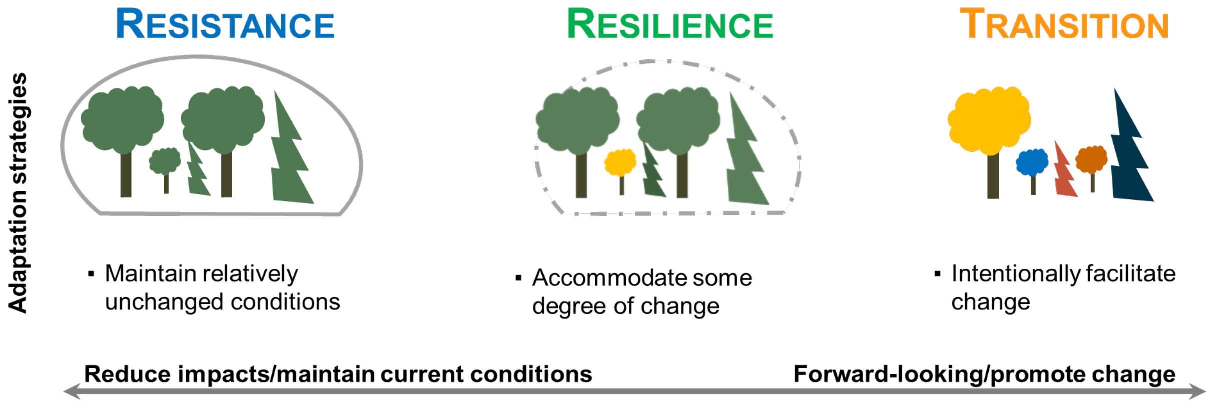
Resist
Direct
Accept
Intensity of intervention
Deviation from historical conditions



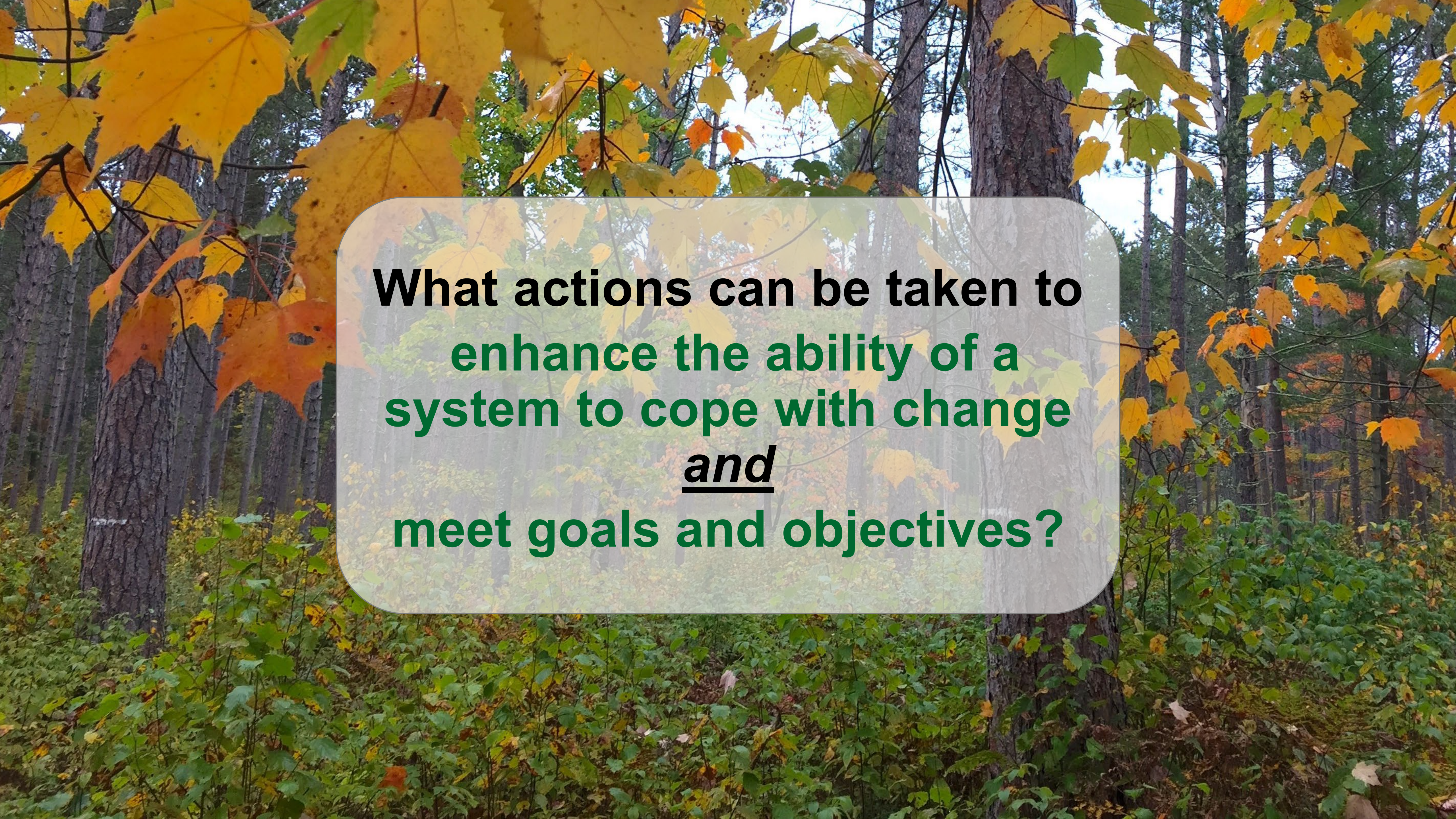
a. Current CSF as framed in academic literature
Sustainable Forest Management
Climate Smart Forestry
SFM without climate benefits
b. Enhanced use of CSF found in applied practice
Climate Smart Forestry
Restoration
Sustainable Forest Management
Avoided Conversion



SFM – inclusion of wide-range of ecosystem services
Promoting adaptation and mitigation
Protection through enhanced health and vitality
Peripheral indicators
Core indicators
Climate-smart forestry
Core indicators
Peripheral indicators
Maintaining forest biodiversity
Integration of social dimensions
Ensuring the provision of ecosystem services



Adaptation strategies
RESISTANCE
RESILIENCE
TRANSITION
▪ Maintain relatively unchanged conditions
▪ Accommodate some degree of change
▪ Intentionally facilitate change
Reduce impacts/maintain current conditions
Forward-looking/promote change



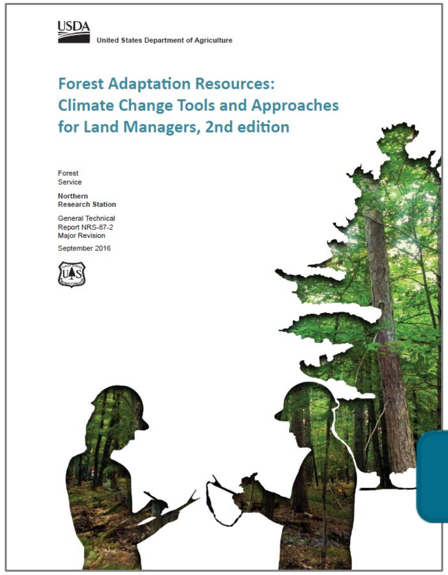
What actions can be taken to enhance the ability of a system to cope with change

and

meet goals and objectives?

Adaptation Workbook & Adaptation Resources

- Flexible 5-step workbook designed for a variety of landowners with diverse goals
- Relies on manager's expertise and judgement
- Creates **clear rationale** for actions by connecting them to **broader adaptation ideas**
- **Does not make recommendations**
- **Includes:**
  - Adaptation workbook
  - Adaptation strategies for different resource areas (menus)



Swanston et al. 2016 (2nd edition)

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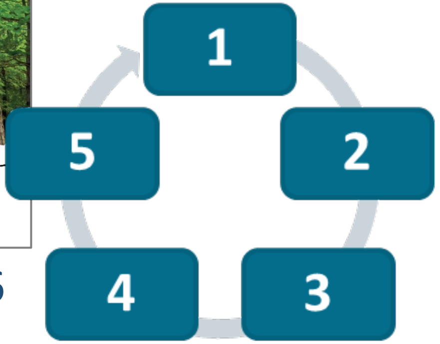
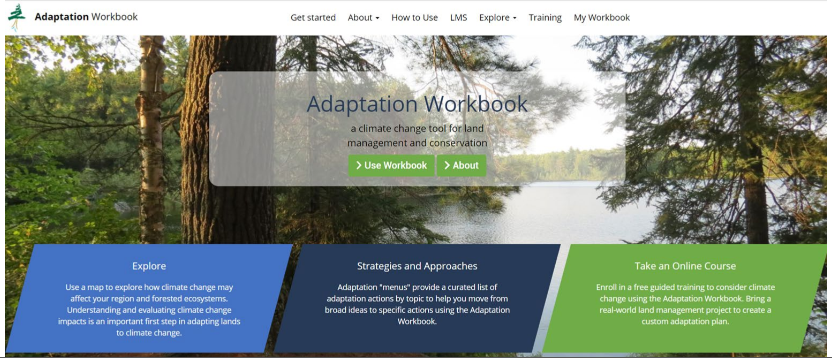
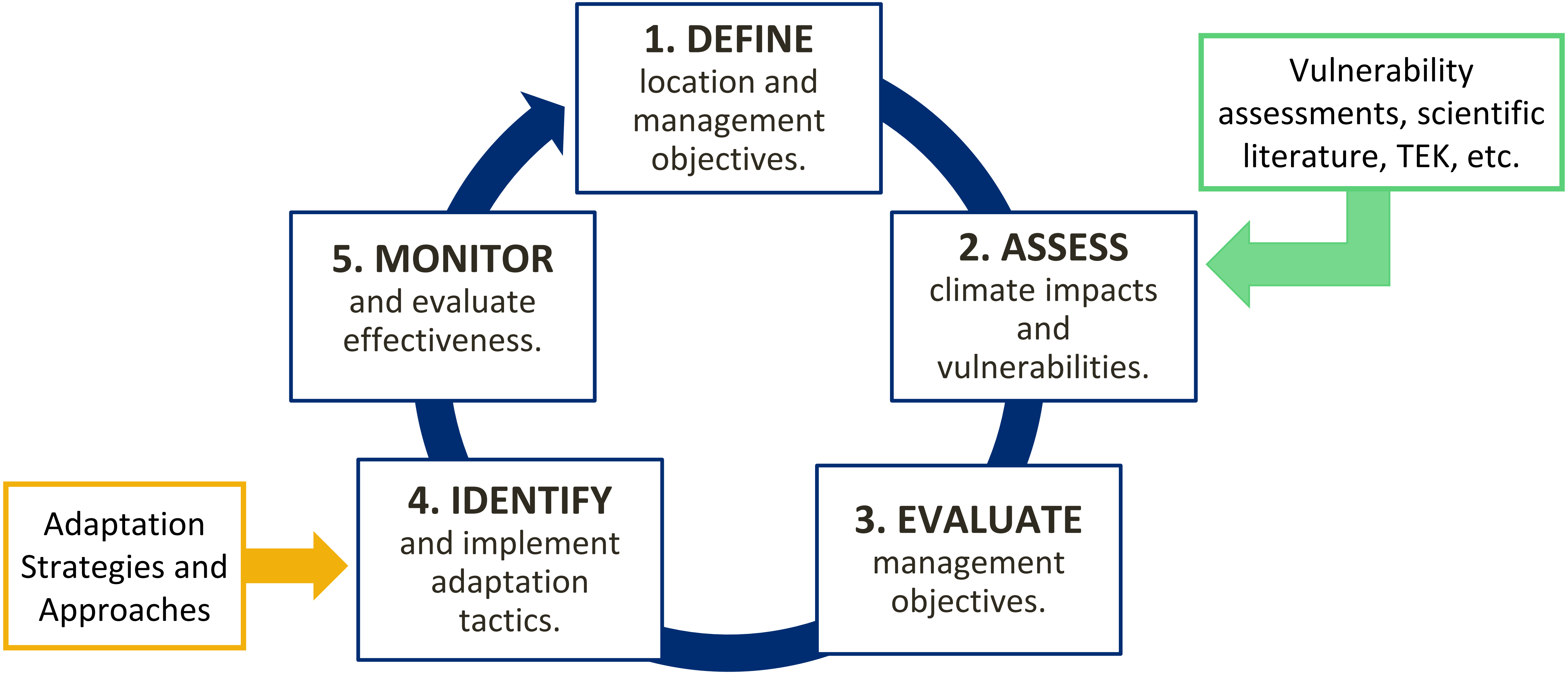




Download at: https://doi.org/10.2737/NRS-GTR-87-2 or use online at www.AdaptationWorkbook.org

Adaptation Workbook



Adaptation Options: A spectrum, not strict categories

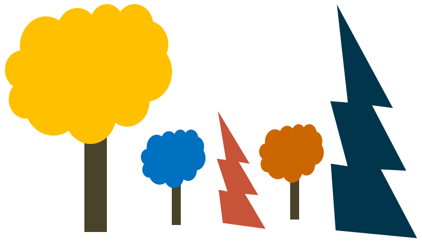
RESISTANCE

- Improve defenses of forest against change and disturbance
- Maintain relatively unchanged conditions

RESILIENCE

- Accommodate some degree of change
- Return to prior reference condition following disturbance

TRANSITION



- Intentionally facilitate change
- Enable ecosystem to respond to changing and new conditions

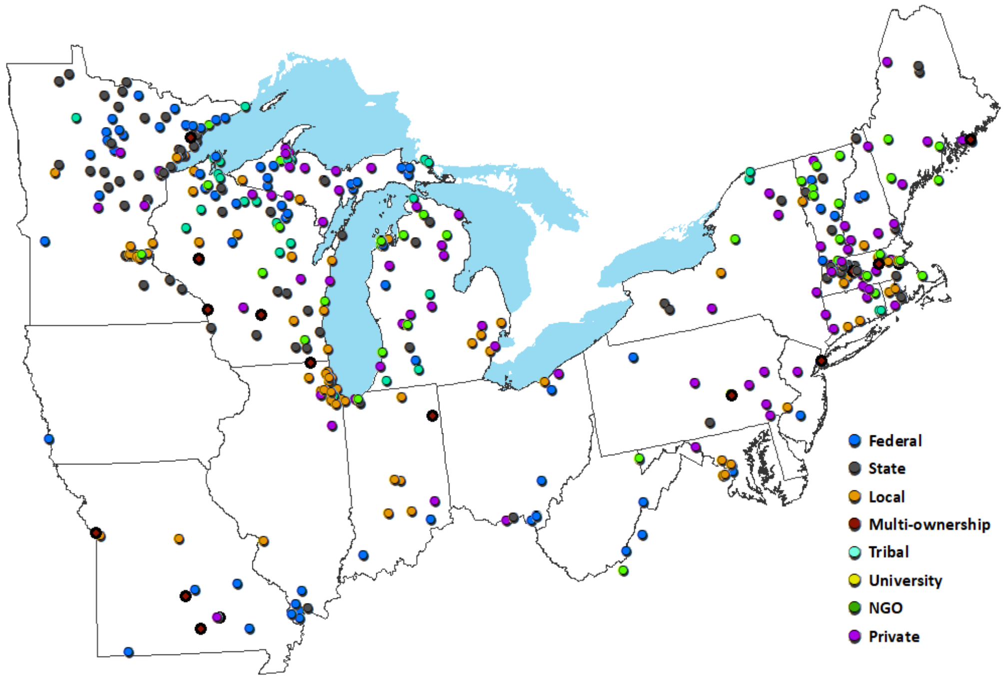
Reduce impacts/maintain current conditions ⟷ **Forward-looking/promote change**

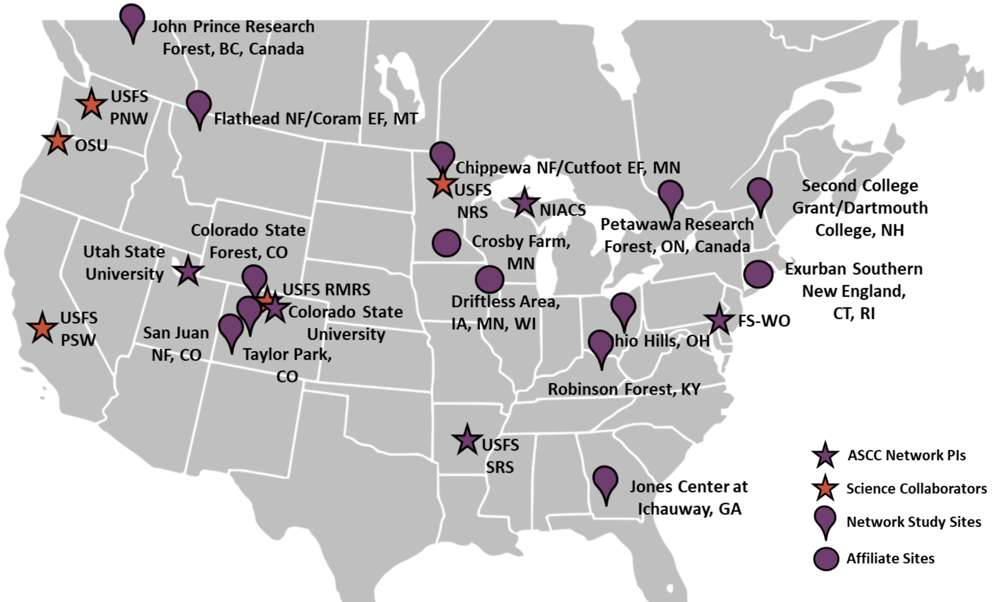
Millar et al. 2007, Swanston et al. 2016, Nagel et al. 2017

Adaptation in Action

Adaptation Workbook projects incorporate climate change considerations into planning and decision-making.

- **Adaptation Demonstrations –** 500+ examples of climate-informed management via the Climate Change Response Framework (www.forestadaptation.org)
- **Silvicultural Trials –** Experimental trials testing adaptation treatments at 8 core sites via Adaptive Silviculture for Climate Change Network (www.adaptivesilviculture.org)





Adaptive Silviculture for Climate Change Network

ASCC
Adaptive Silviculture for Climate Change

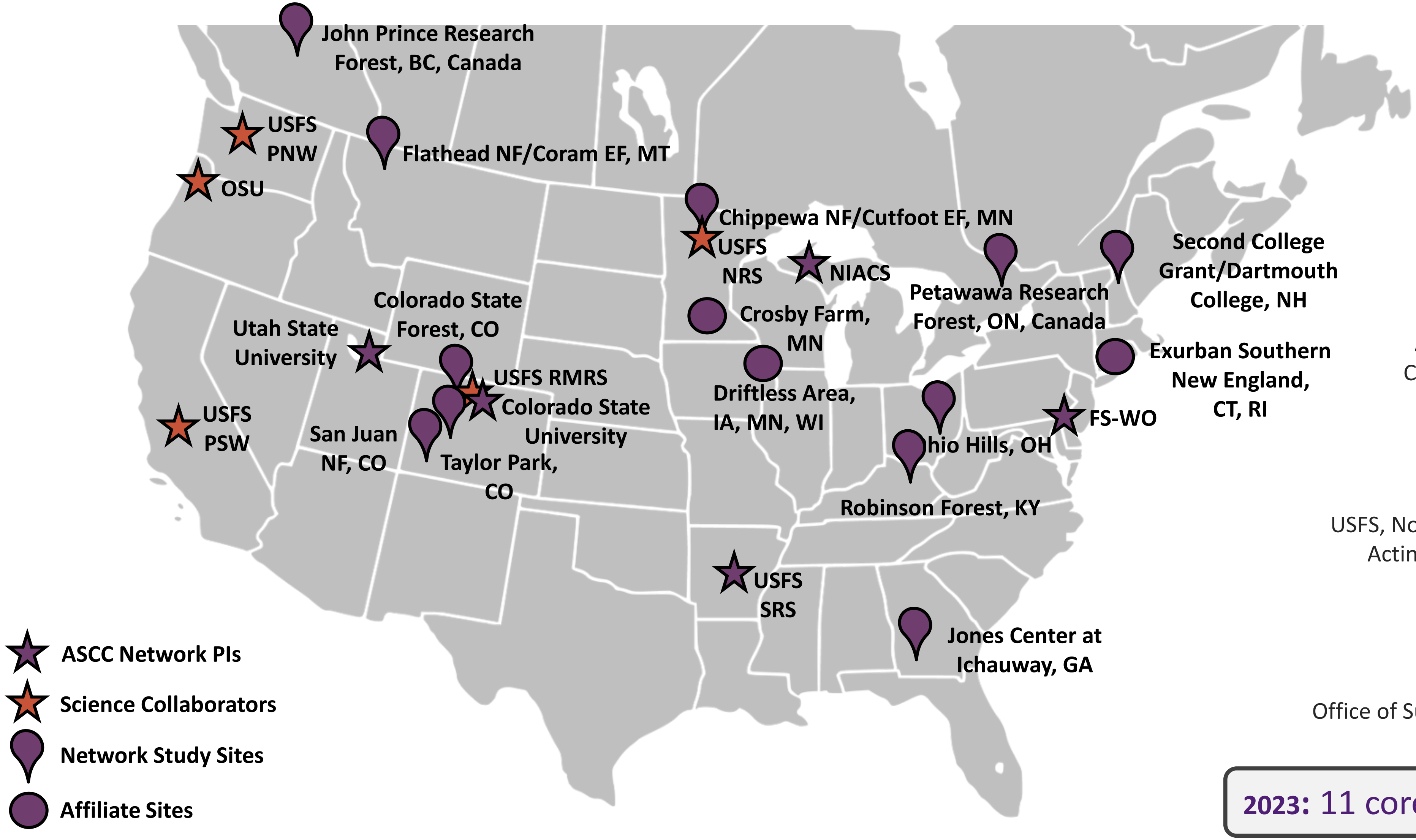
***Project Goals*:**

1) Introduce managers to tools and approaches to integrate climate change into silvicultural decision making that meets management goals and objectives

2) Co-develop robust, operational examples of how to integrate climate change adaptation into silvicultural planning and on-the-ground actions to foster resilience to the impacts of climate change and enable adaptation to uncertain futures

Adaptive Silviculture for Climate Change Network

Adaptive Silviculture for Climate Change



Linda Nagel, Lead PI
Professor and Dean
Utah State University

Courtney Peterson
ASCC Program Manager
Colorado State University
NIACS, SWCH

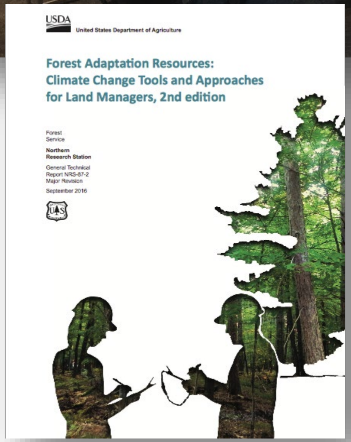
Maria Janowiak, Co-PI
USFS, Northern Research Station
Acting Director, NIACS, NFCH

Chris Swanston, Co-PI
USFS, Director
Office of Sustainability and Climate

2023: 11 core sites, 3 affiliate sites

ASCC Network Website: www.adaptivesilviculture.org

ASCC Study Design & Collaborative Workshop



Common Design *Across All Forests*

- **Treatment Themes:** ***Adaptation Options***
  - Resistance
  - Resilience
  - Transition
  - No Action
- **Minimum Study Design Elements**
  - Replication
  - Stand/EU Size
  - Monitoring Guidelines
  - Evaluation Window

Site Specifics *Unique to Individual Forests*

- Forest Type or Ecosystem
- Study Sites/Layout
- Management Objectives
- Adaptation Approaches & Tactics
- Final Monitoring Plan

Collaborative Workshop

Developing the Experimental Treatments

For <u>each</u> experimental treatment (Resistance, Resilience, Transition):

Desired Future Condition

↓

Management objectives

↓

Silvicultural practices (tactics)

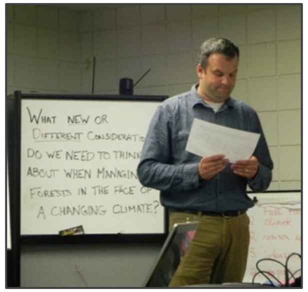
What is the desired structure and function (*desired future condition*)?

<u>Keep in mind key variables/outcomes</u>:

- **Species composition**
- **Forest health**
- **Forest productivity**
- **Response to disturbance**

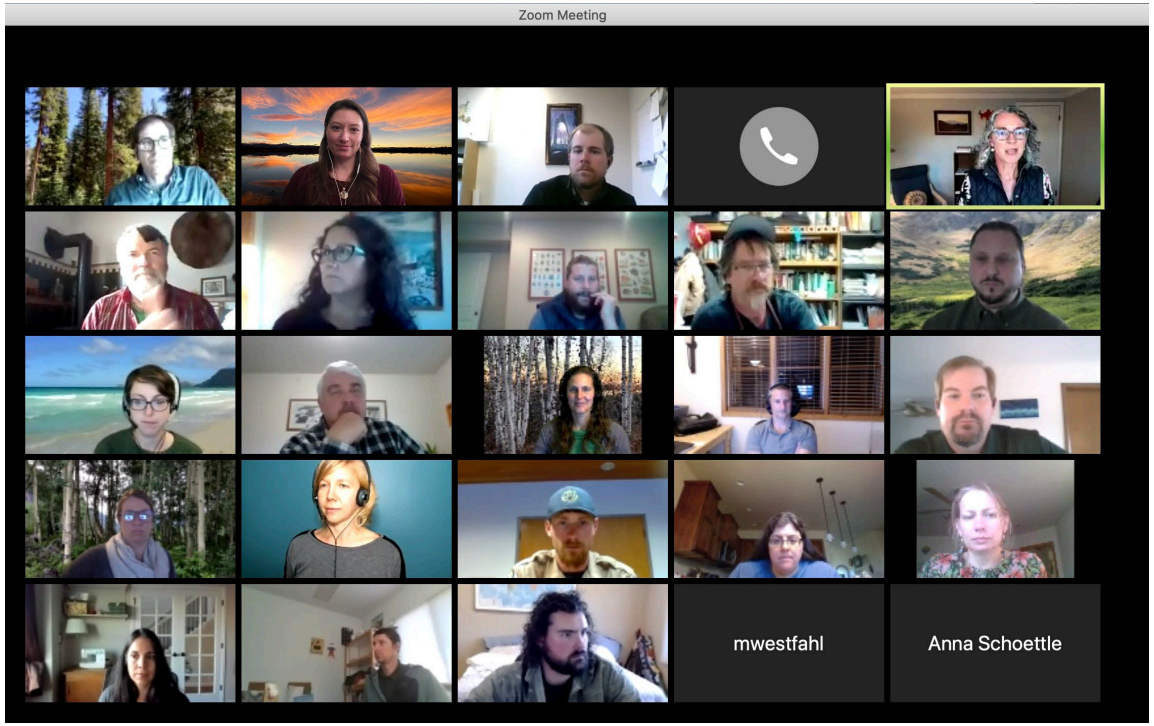
<u>For each silvicultural practice (tactic)</u>:

- **Timeframes**
- **Benefits**
- **Drawbacks and Barriers**
- **Practicality**



First Workshop: MN, June 2013

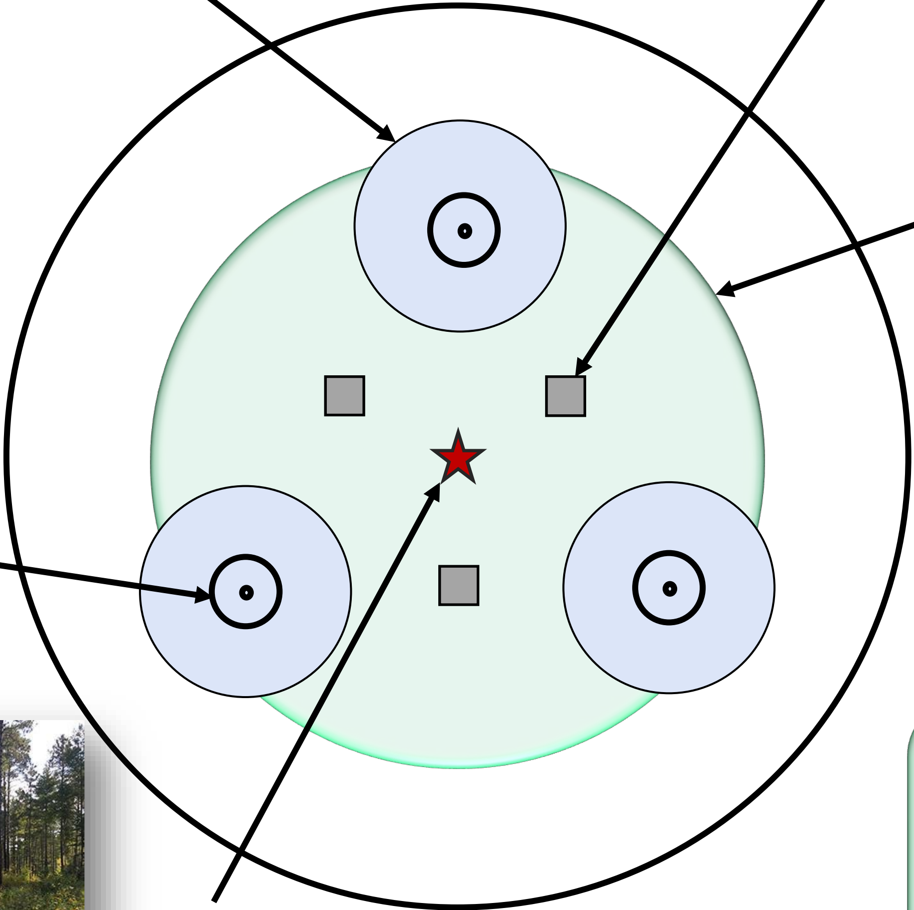
First Virtual Workshop: CO, Dec 2020



ASCC Plot Design

Small Tree Plot (Adv Regen)
(3, 0.004 ha)

Ground Layer Plot
(3, 1-m²)



Sapling Sub-Plot
(0.04 ha)

Shrub Plot
(2, 5-m²)

Annular Plot
(0.08 ha)

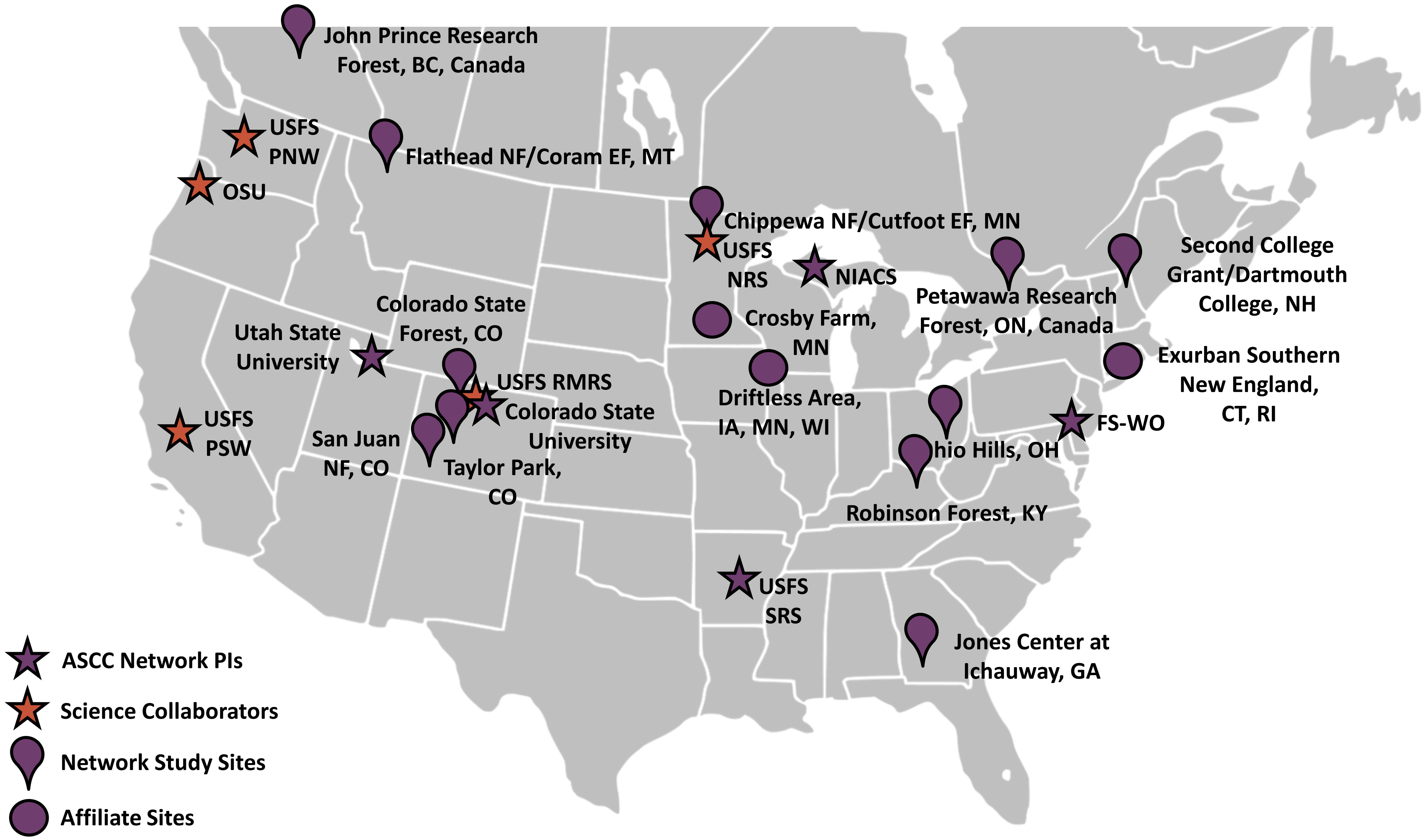
**Species, Ht, DBH, snags + decay class, forest health metrics*

LAI and Photos
Microclimate stations on sub-set of plots

Key Response Variables Monitored Across All Sites (Overstory, Midstory, & Understory):

- Species composition, density, diversity, etc.
- Forest health (mortality, local indices)
- Productivity (increment, biomass)

Cutfoot Experimental Forest / Chippewa NF



ASCC Network Website: www.adaptivesilviculture.org

Cutfoot Experimental Forest / Chippewa NF

ASCC
Adaptive Silviculture for Climate Change

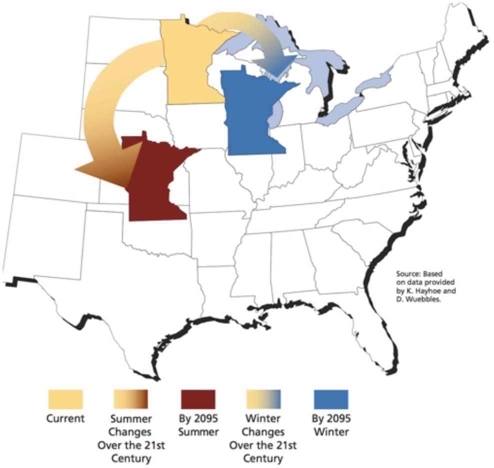
Our first ASCC site turned 10 years old!!

ASCC Network Website: www.adaptivesilviculture.org

Cutfoot Experimental Forest, MN

Cutfoot EF, Chippewa NF, MN

- Red pine-dominated, mixed species
- Fire origin 1918
- 180 ft^2/ac (41 m^2/ha), overstocked
- Climate concerns include increased drought stress, increased risk of wildfire, and increased insect and disease outbreaks



RESISTANCE

Uniform (free) thin

100-120 ft^2/ac (23-28 m^2/ha)

Maintain RP, current spp

RESILIENCE

Variable density thinning

20% gaps / 20% reserves / matrix 110 ft^2/ac (25 m^2/ha)

Keep RP dominant

Future-adapted native spp

TRANSITION

Irregular shelterwood

20% gaps / matrix 60-80 ft^2/ac (13-18 m^2/ha)

Heterogeneity spp and structure

Future-adapted native and *novel* spp

Reduce impacts/ maintain current conditions ⟷ **Forward-looking/ promote change**

Cutfoot Experimental Forest, MN

Cutfoot EF Early Results

Forest Ecology and Management 451 (2019) 117539
Contents lists available at ScienceDirect
Forest Ecology and Management
journal homepage: www.elsevier.com/locate/foreco

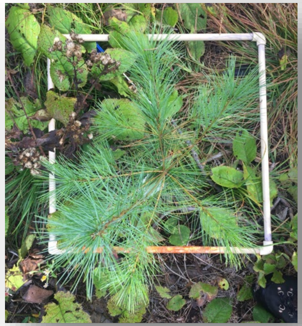
Forest adaptation strategies aimed at climate change: Assessing the performance of future climate-adapted tree species in a northern Minnesota pine ecosystem

Jacob J. Muller[a,*], Linda M. Nagel[b], Brian J. Palik[c]

1875
Canadian Science Publishing
ARTICLE

Comparing long-term projected outcomes of adaptive silvicultural approaches aimed at climate change in red pine forests of northern Minnesota, USA

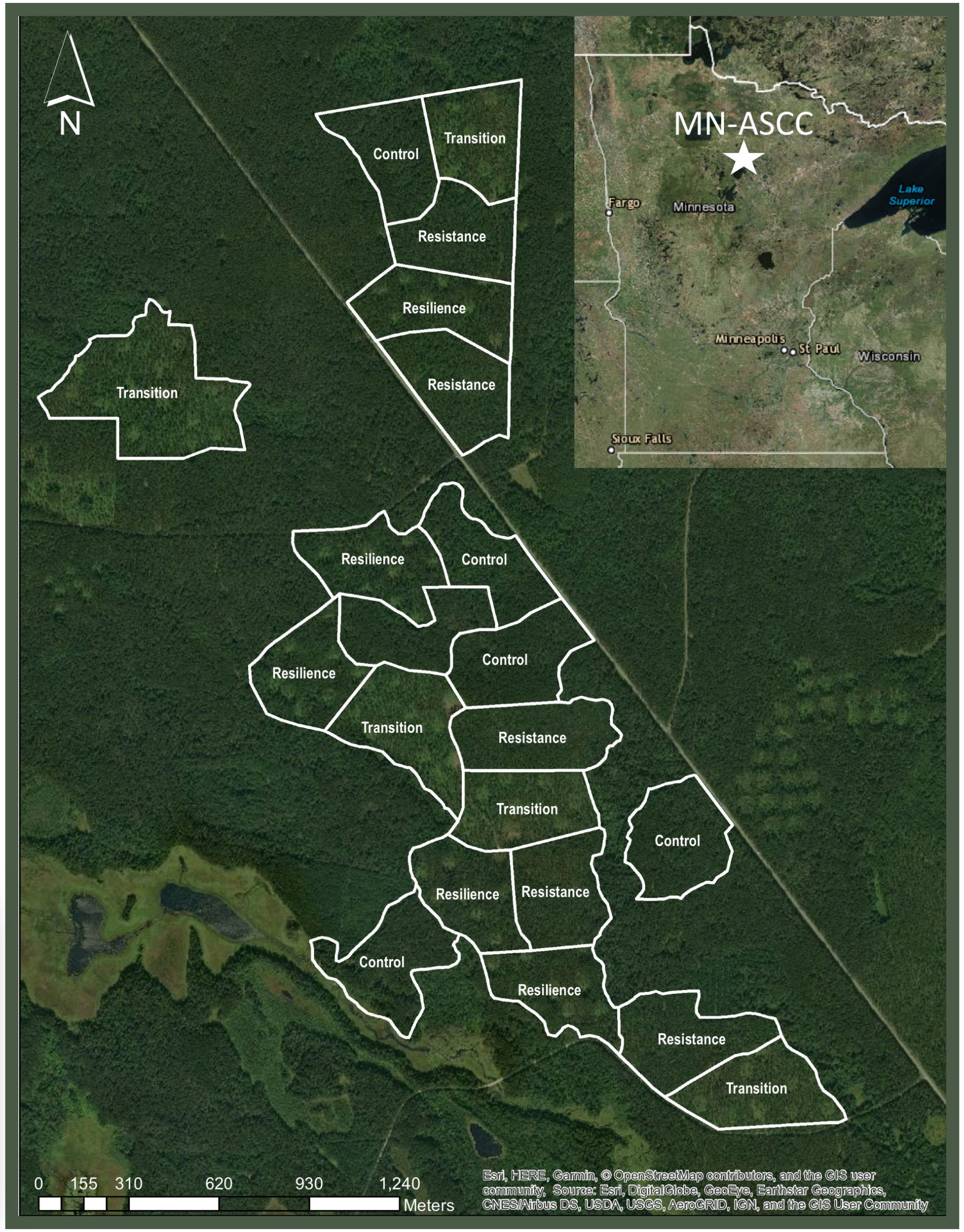
Jacob J. Muller, Linda M. Nagel, and Brian J. Palik


Eastern white pine


Ponderosa pine


Northern red oak


White oak

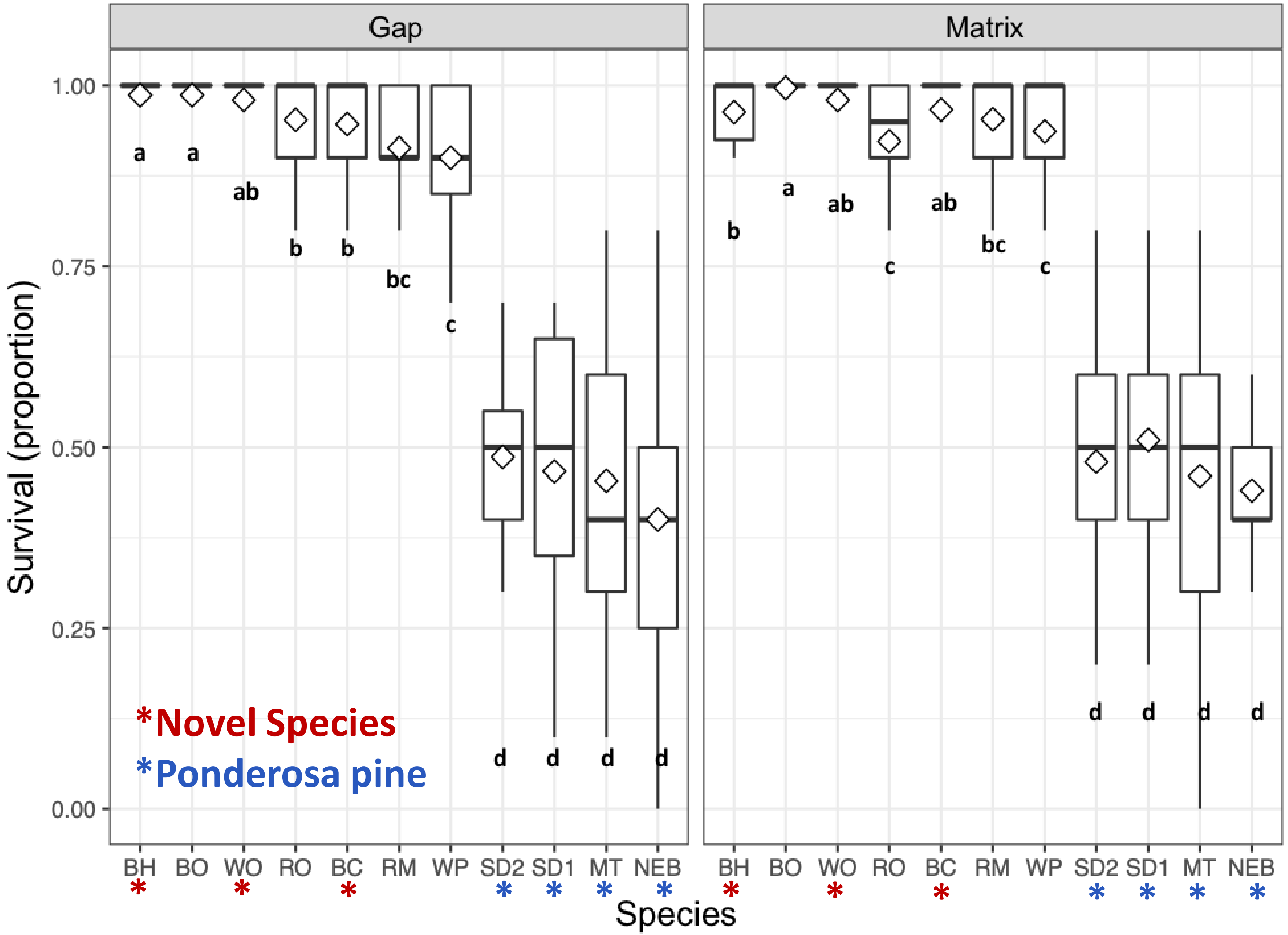


3-year Seedling Survival

Muller, Nagel and Palik. 2019. *Forest Ecology and Management* 451 (2019) 117539

BC – Black Cherry*
BH – Bitternut Hickory*
BO – Bur Oak
RM – Red Maple
RO – Northern Red Oak
WO – White Oak*

SD1 – South Dakota 1 Ponderosa Pine*
SD2 – South Dakota 2 Ponderosa Pine*
MT – Montana Ponderosa Pine*
NEB – Nebraska Ponderosa Pine*
WP – Eastern White Pine



Key Findings

- **Novel species were among those species with highest levels of survival**
- **Ponderosa pine had significantly lower levels of survival than other species**
- **Understory shrub cover was a strong predictor of seedling survival**
- **No real impact of overstory (gap vs. matrix) on survival**

3-year Seedling Growth

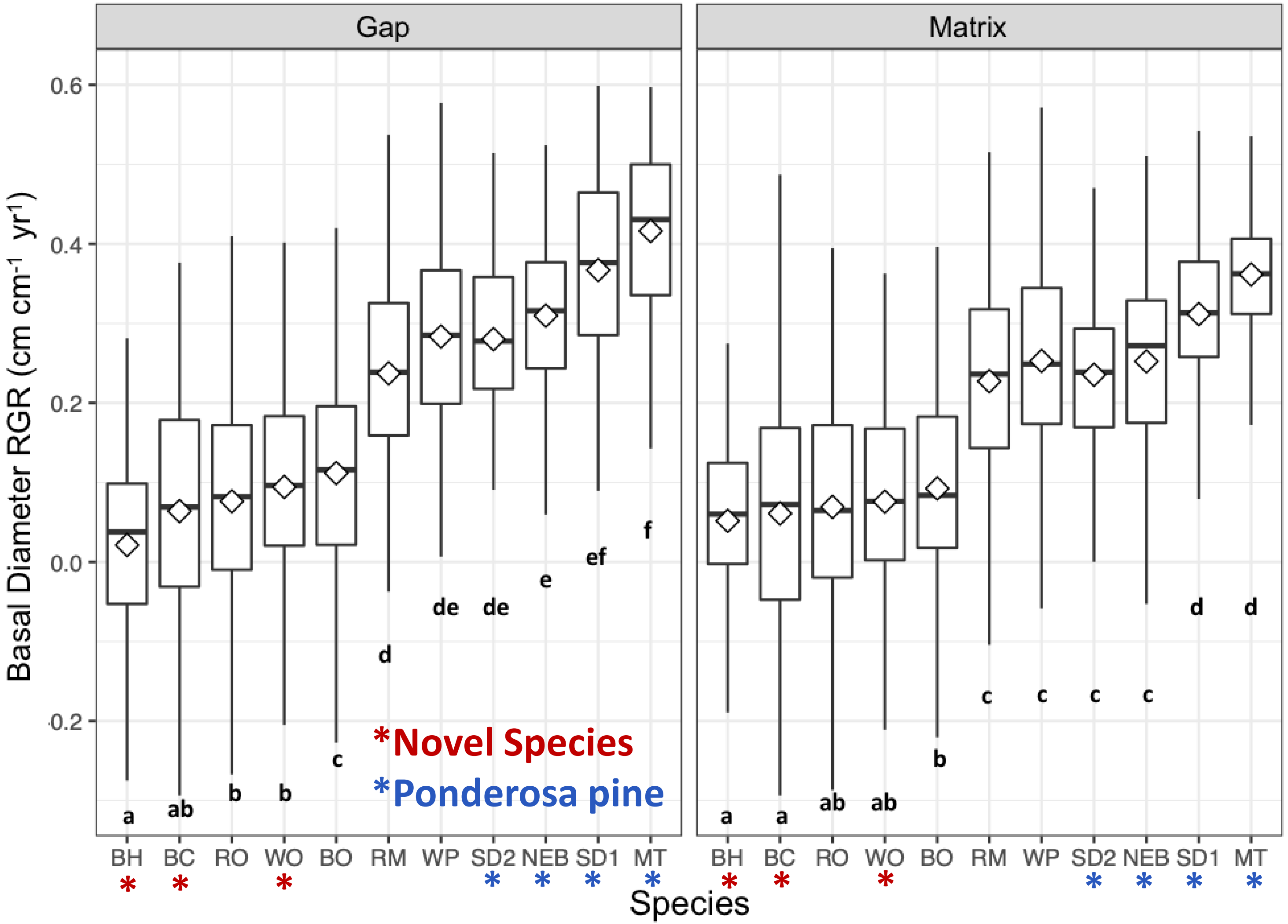
Muller, Nagel and Palik. 2019. *Forest Ecology and Management* 451 (2019) 117539

BC – Black Cherry*
BH – Bitternut Hickory*
BO – Bur Oak
RM – Red Maple
RO – Northern Red Oak
WO – White Oak*

SD1 – South Dakota 1 Ponderosa Pine*
SD2 – South Dakota 2 Ponderosa Pine*
MT – Montana Ponderosa Pine*
NEB – Nebraska Ponderosa Pine*
WP – Eastern White Pine

Key Findings

- **Native species significantly outgrew novel species (*sans* Ponderosa)**
- **Ponderosa pine significantly outgrew other species**
- **Understory vegetation was not a predictor of RGR**
- **Species with a high to moderate shade tolerance grew more in gaps vs. matrix**



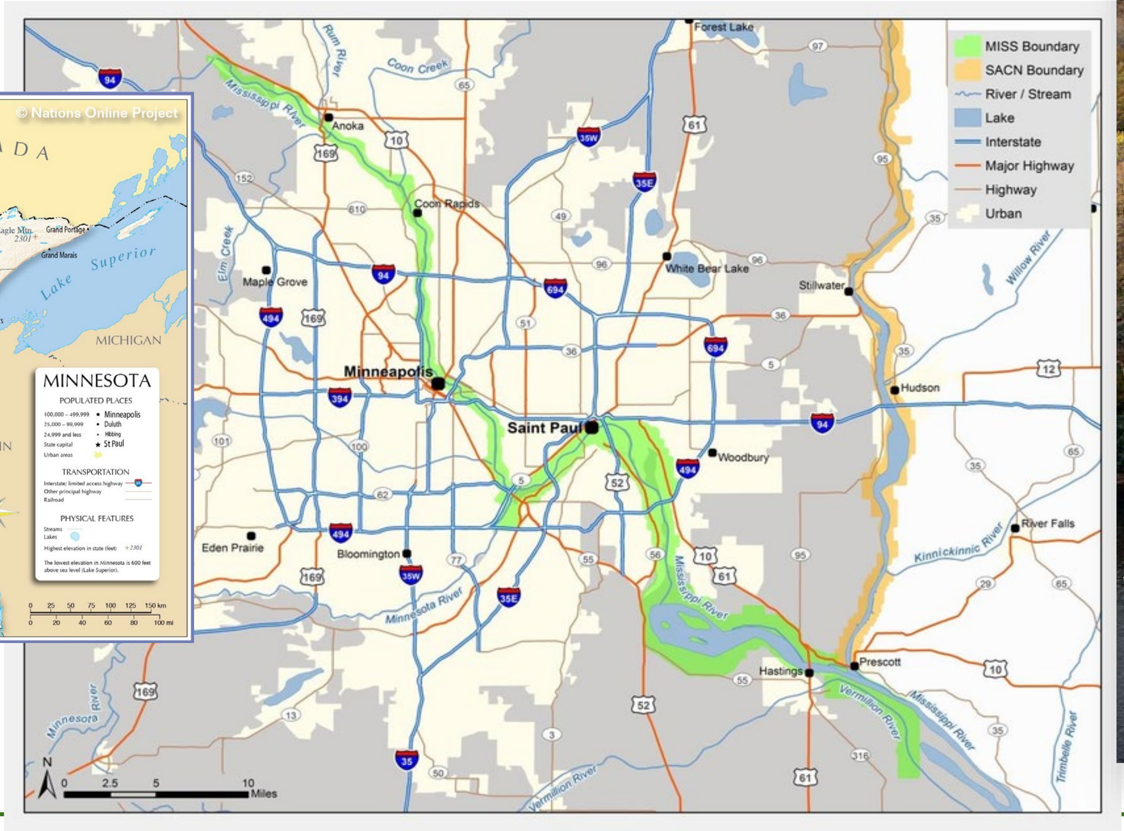
Adaptive Silviculture for Climate Change

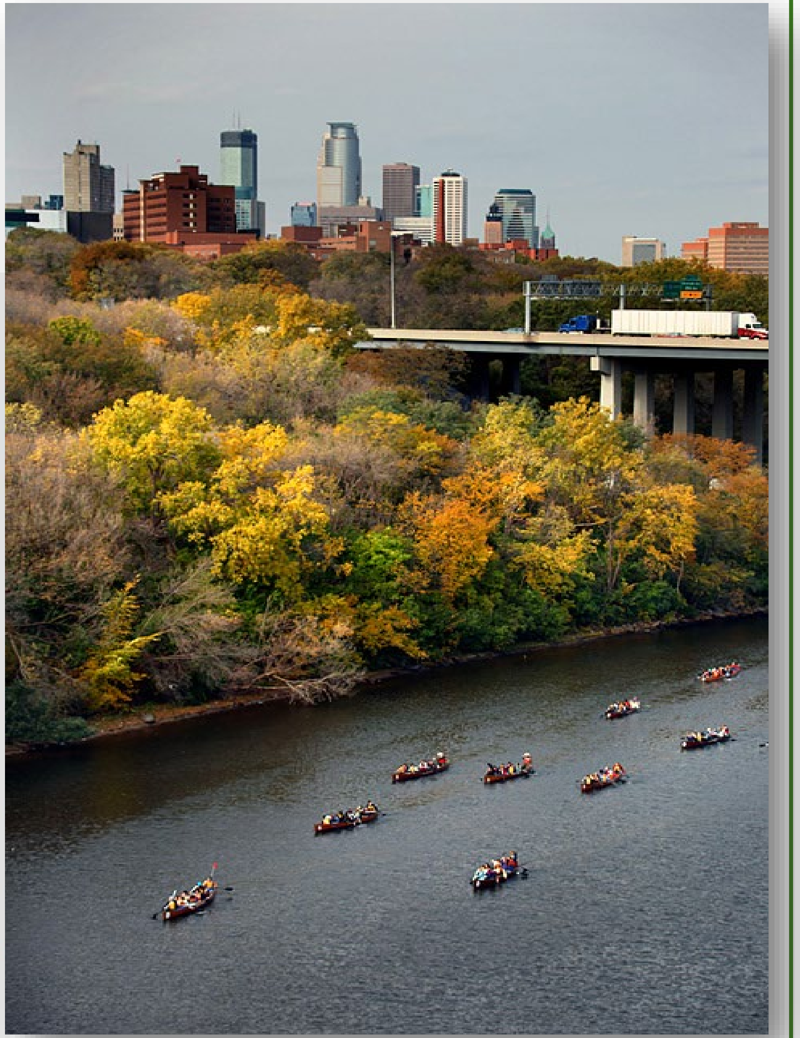
Crosby Farm Regional Park

ASCC Network Website: www.adaptivesilviculture.org

Mississippi National River and Recreation Area

- 72 miles of river throughout the heart of Minneapolis/St. Paul, est. 1988
- 54,000 acres | 25 cities, 22 Tribal Nations, 5 counties, 2 state agencies, and 3 federal agencies
- A unifying focus on the Mississippi River



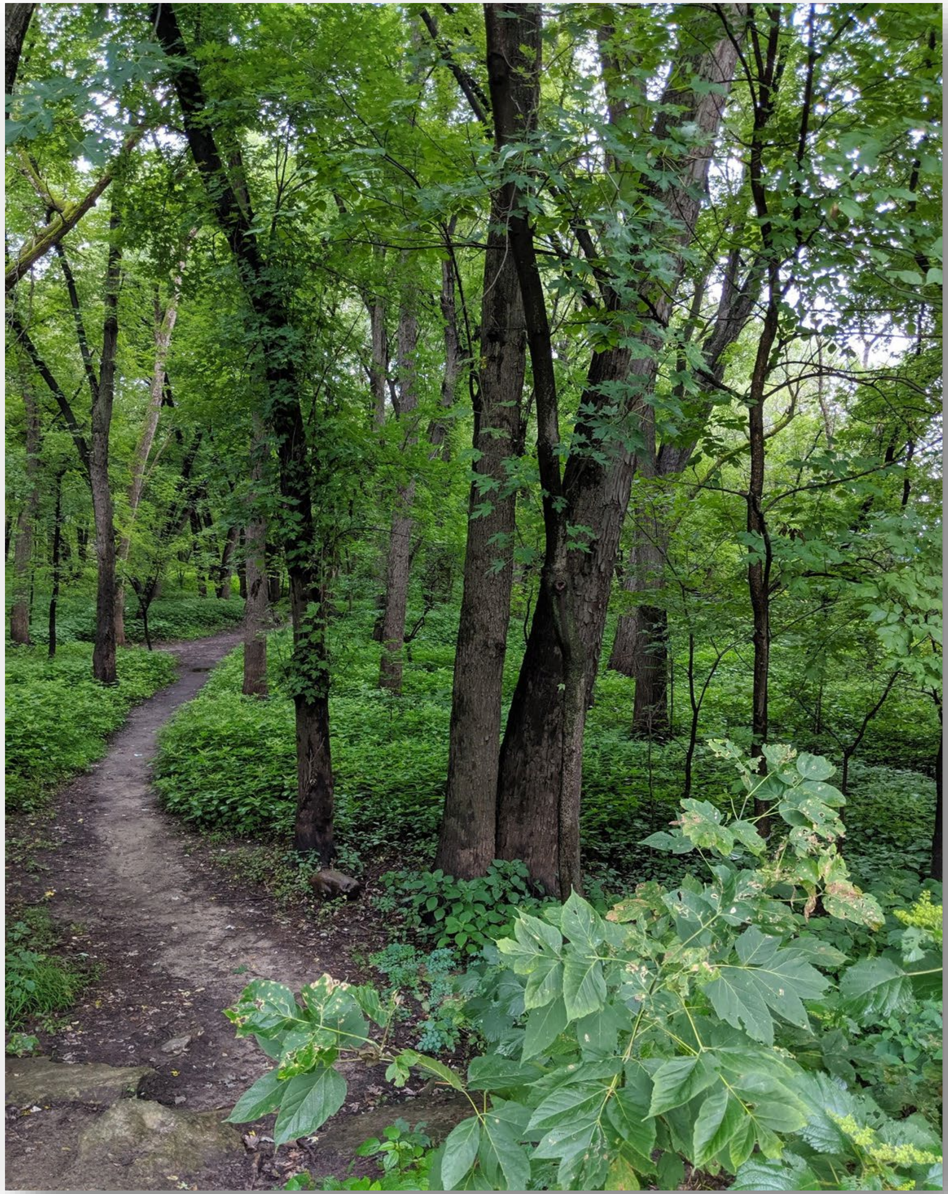


Crosby Farm Regional Park

https://parkconnection.org/ascc

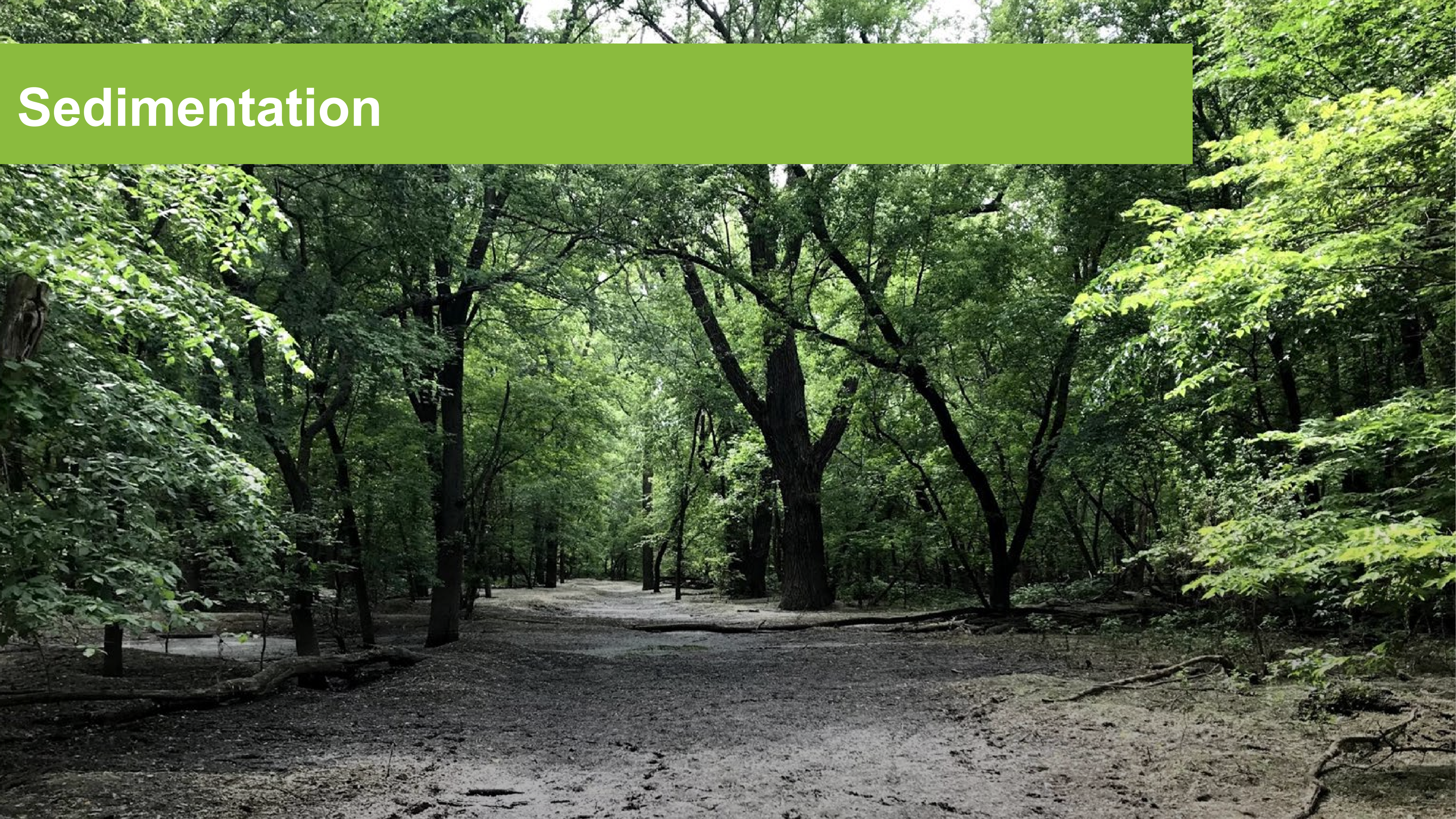
- Largest natural park in the Saint Paul system of parks at **736 acres**
- Important component in protecting the **biodiversity** of the Mississippi River corridor through the Twin Cities, Minnesota
- An outdoor destination including **6.7 miles** of paved trails, hunting, fishing, birdwatching, picnicking, canoeing, boating, & winter recreation

Plant for the Future in the Mississippi National River and Recreation Area



Increased flood frequency and severity

Sedimentation



Invasive species

Crosby Farm, Mississippi National River and Recreation Area, MN

Crosby Farm, St Paul, MN

- Floodplain forest: green ash, silver maple, hackberry, boxelder, cottonwood, American elm
- Climate concerns include increased temperatures, especially at night; increased precipitation in heavier rain and flooding events; increased drought stress in the summer and dramatic decreases in SWE

RESISTANCE

Maintain closed canopy condition of current species composition (Floodplain forest ash-elm cover type)

Promote or enhance native regeneration (natural or planted)

RESILIENCE

Promote future-adapted (flood and drought-tolerant) species native to the Miss. River

Create gaps for regeneration utilizing natural gaps (e.g. dying ash pockets), removing hazard trees, and creating additional gaps for desired species

TRANSITION

Incorporate future-adapted tree species (from farther south along the Mississippi River and southern genotypes of native species from IA, IL, and MO)

Create gaps with feathered edges to establish diverse microsites for planting

Reduce impacts/ maintain current conditions ↔ Forward-looking/ promote change

Site	Starting Conditions	RESISTANCE – maintain relatively unchanged conditions	RESILIENCE – allow some change, eventual return to reference	TRANSITION – facilitate change, encourage adaptive response
Cutfoot EF	104-yr old red pine	Uniform (free) thin	Variable density thin	Irregular shelterwood
San Juan NF	Warm-dry mixed conifer	Thin (even-spacing)	Selection (multi-cohort)	Patch cuts – openness
Jones Center	Longleaf pine-hardwood	Retain longleaf pine	Thin & burn	Thin & burn
Flathead NF/Coram EF	Mixed conifer/western larch	Commercial thinning from below	Group selection	Irregular seed tree with reserves
Second College Grant	Northern hardwoods/red spruce mixedwoods	Singe-tree selection	Hybrid single-tree selection & group selection (VDT)	Continuous cover irregular shelterwood (VDT)
MNRRA / Crosby Farm	Floodplain forest ash-elm	All trees removed within 1/10th acre plot and planted		
Petawawa RF	Great Lakes St. Lawrence Mixedwood Shield	2-cut uniform shelterwood	Expanding gap irregular shelterwood	Clearcut with seed tree
S. New England Exurban	Oak-hickory (CT &RI)	Prep shelterwood cut	Irregular shelterwood	Expanding gap irregular shelterwood
Colorado State Forest	Subalpine spruce-fir	Free thin	Group selection; matrix thin	Group selection; matrix thin
John Prince RF	Stuart Dry Warm Sub-boreal Spruce Variant	Hybrid group selection	Hybrid group selection with VDT matrix	Shelterwood
Driftless Area	Dry-mesic oak forests	Free thin to ~B-line	Continuous cover irregular shelterwood	Clearcut with reserves
Ohio Hills	Oak/mixed mesophytic	Thin from below	Expanding gap / irregular shelterwood (VDT)	Group selection with variable retention
Taylor Park	Lodgepole pine	Thin from above	2-step shelterwood; VDT matrix	Clearcut with reserves
Robinson Forest	Mixed mesophytic oak	2- or 3-step shelterwood	Extended irregular shelterwood	Variable retention harvest

Forest Assisted Migration (FAM)

ASCC

Site	**RESISTANCE** – maintain relatively unchanged conditions	**RESILIENCE** – allow some change, eventual return to reference	**TRANSITION** – facilitate change, encourage adaptive response
Cutfoot EF	No planting	PE	PE, RE, SM
San Juan NF	No planting	No planting	Maybe PE
Jones Center	No planting	No planting	PE
Flathead NF/Coram EF	No planting	PE	PE, RE
Second College Grant	No planting	No planting	PE, RE
MNRRA / Crosby Farm	Local/PE	PE, RE	SM
Petawawa RF	PE	PE, RE	PE, RE, SM
S. New England Exurban	No planting	PE in gaps	PE, RE
Colorado State Forest	No planting	PE	PE, RE, SM
John Prince RF	PE	PE	PE, RE, SM
Driftless Area	No planting	PE	PE, RE, SM
Ohio Hills	No planting	PE	PE, RE
Taylor Park	No planting	RE	RE
Robinson Forest	No planting	Maybe PE	PE, RE, maybe SM

FAM Options:

- Population Expansion (PE)
- Range Expansion (RE)
- Species Migration (SM)

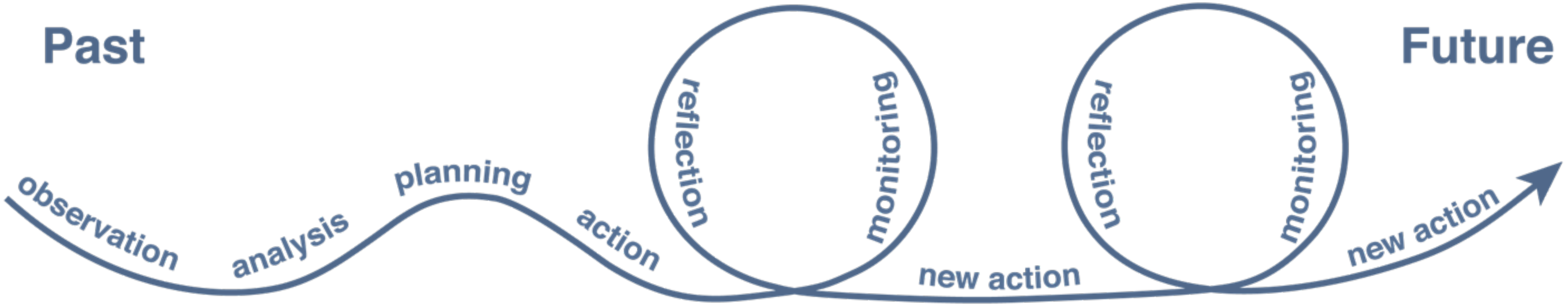
Future Questions

ASCC was built to address high-impact, cross-site research questions centered on climate-adaptive management, such as:

- Do treatments achieve what they were designed for?
- How do treatments compare across sites?
- Does one treatment (RRT) perform better across all sites?
- Ecological “transformation”
- Success of native vs. novel species
- Overstory impacts on microclimate and seedling success
- Adaptation to large-scale disturbances (drought, fire, insects, diseases, ice storms, hurricanes, etc.)
- Wildlife response to adaptation treatments
- Public perceptions of climate-adaptive management strategies
- Major drivers of change across the ASCC Network sites

Final Thoughts

- There is no single answer for how to respond to climate change. Actions will depend upon where you are working and what you are trying to achieve.
- Science and management can inform each other.
  - Top-down: global/regional information “downscaled” to management scales
  - Bottom-up: place-based expertise & need informs action



Climate Adaptation Vocabulary

Framework				Source
Resist	Resilience	Response		Millar et al. 2007
Resist	Accept	Guide		Aplet & Cole 2010
Restraint	Resilience	Resistance	Realignment	Stephenson & Millar 2011
Refugia	Ecosystem maintenance	Natural adaptation	Facilitate transitions	Magness et al. 2011
Persistence	Change			Stein et al. 2014
Resistance	Resilience	Transition		Swanston et al. 2016
Persistence	Autonomous change	Directed change		Fisichelli et al. 2016a
Resist	Accommodate	Direct		Fisichelli et al. 2016b
Evade | Ameliorate	Build adaptive capacity			Prober et al. 2018
Resist	Accept	Direct		Schuurman et al. 2020
Awareness	Anticipation	Action		Bergstrom et al. 2021