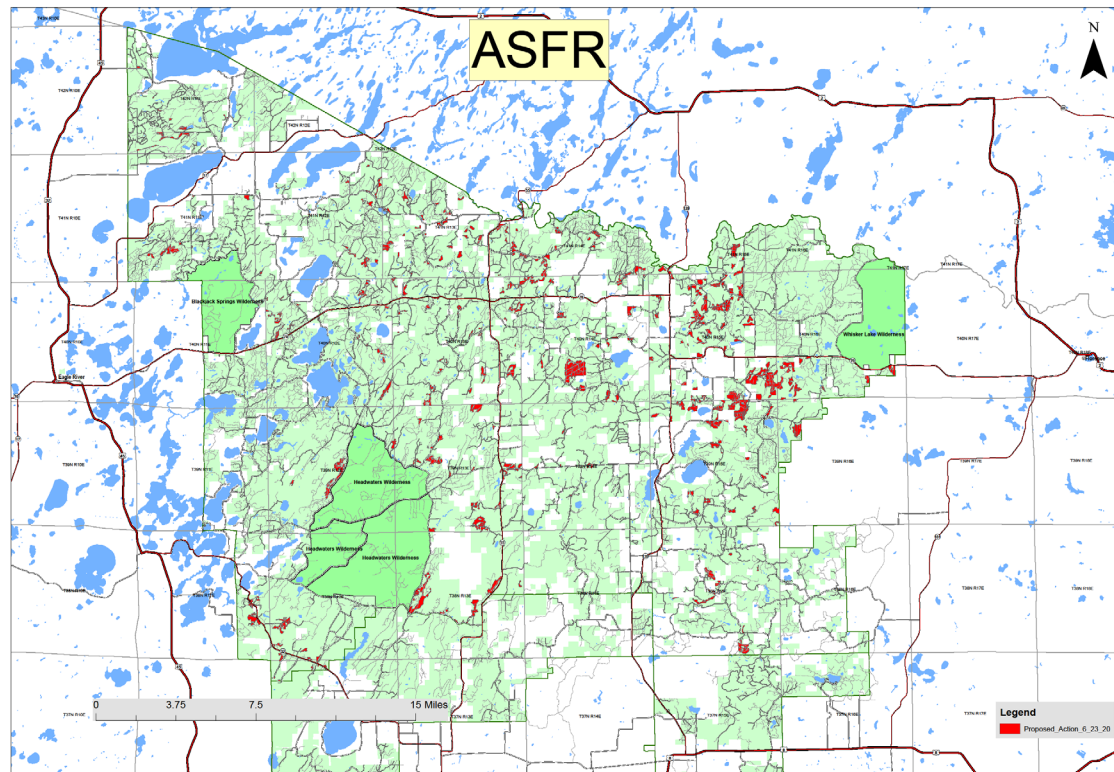


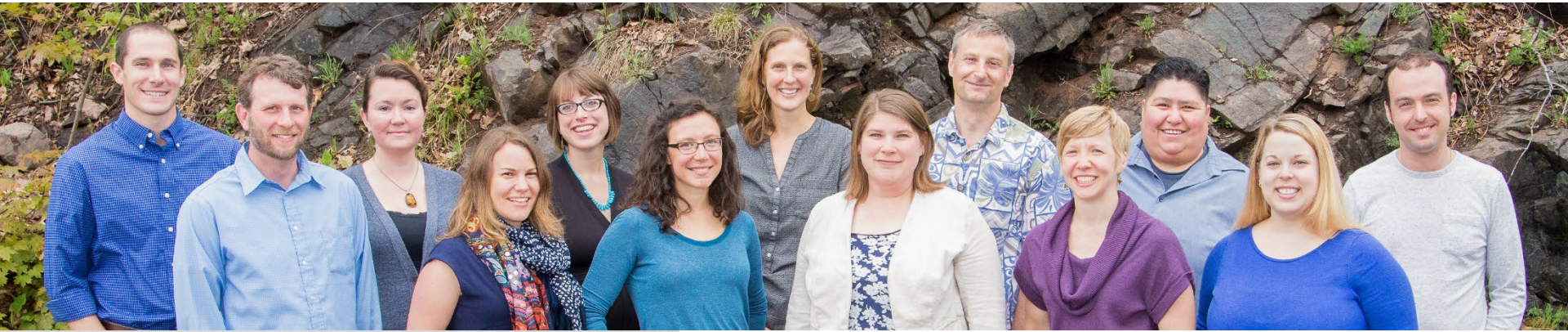
# *Climate Change and the Chequamegon-Nicolet National Forest Aspen-Spruce-Fir Restoration Project*



*September 2020*



# Northern Institute of Applied Climate Science



Chartered by USDA Forest Service, universities, non-profits, and tribal organizations:

- Practical information on **climate adaptation** and **carbon management**
- Adaptation resources
- Technical assistance



# Two Key Questions

1. How might climate change affect the resources that I manage?
2. What management actions could help prepare for those effects?

# Twin concepts for responding to climate change

- Mitigation = actions that reduce the human contribution to the greenhouse gas effect.

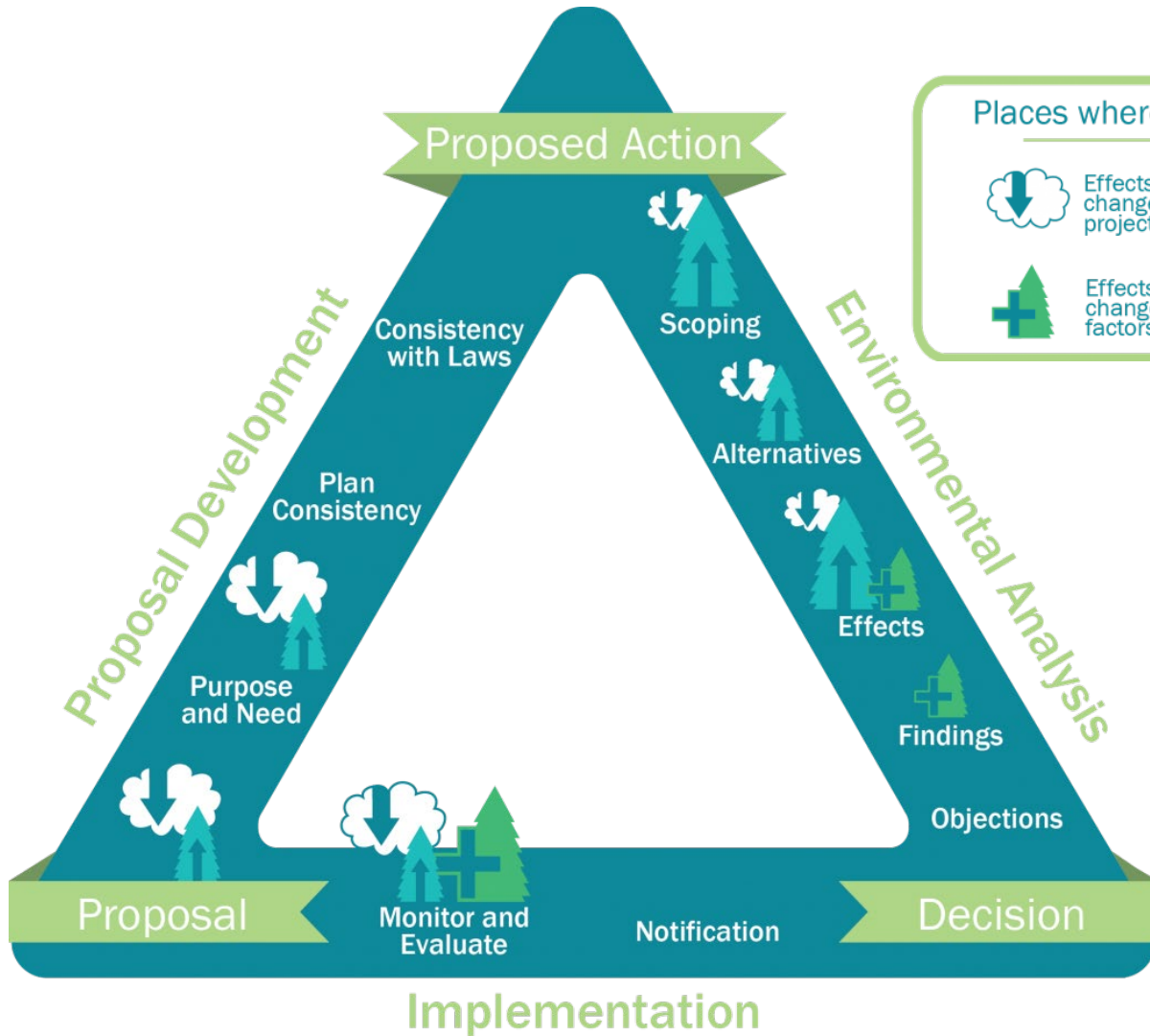


KR 140 12271

- Adaptation = actions to prepare for and adjust to new conditions.



# Climate Change and NEPA



Places where climate change may be considered:



Effects of climate change on a project



Effects of project on climate change



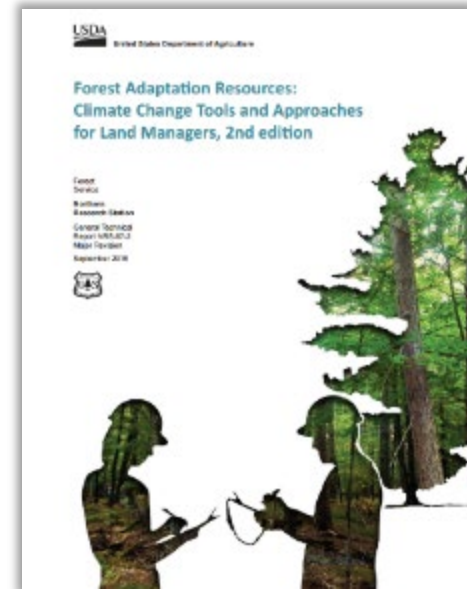
Effects of climate change and other factors

Larger icons indicate greater emphasis, smaller icons indicate less emphasis

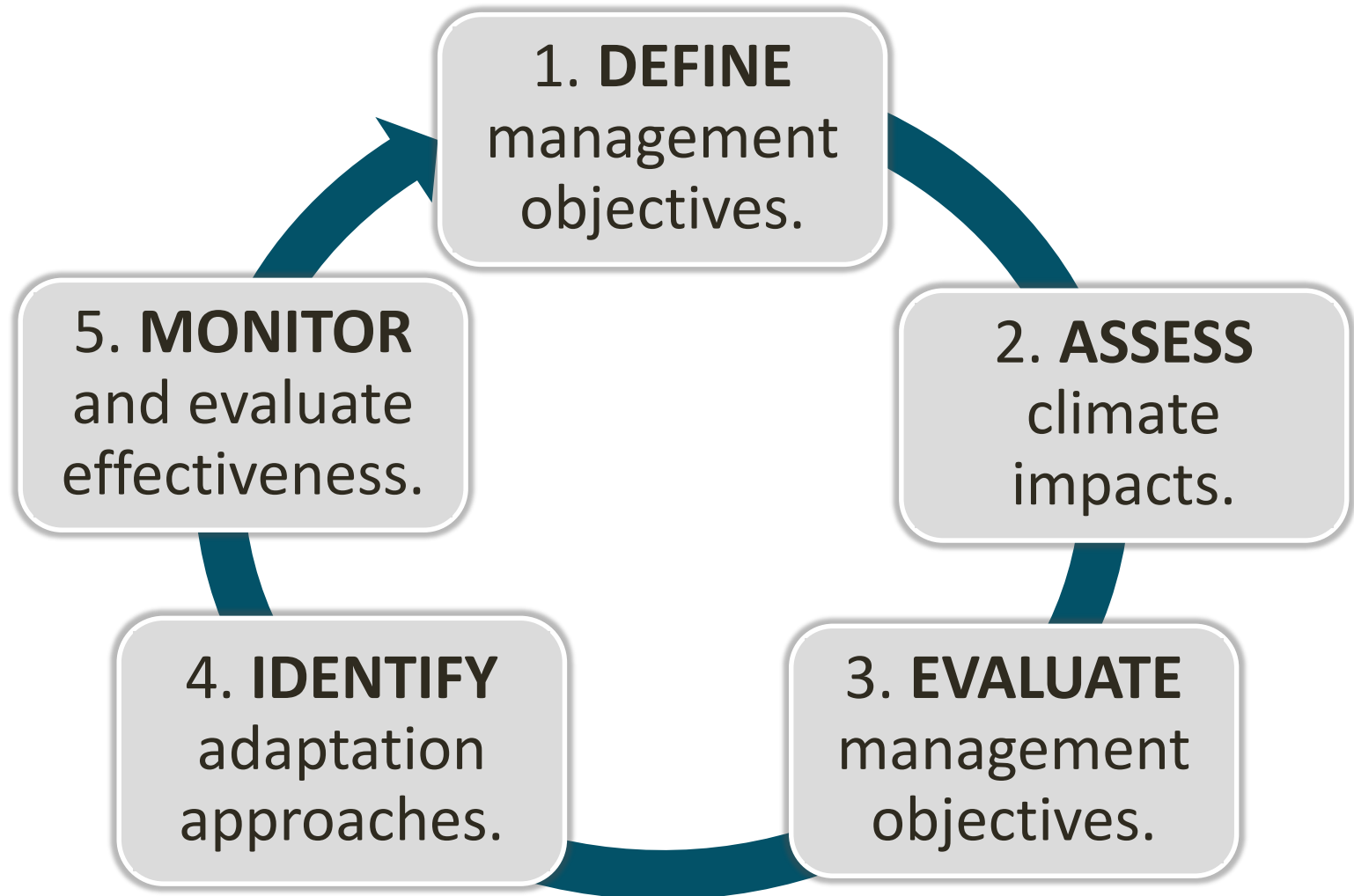
# Forest Adaptation Resources

## *A flexible workbook and menu to address diverse needs*

- Designed for a variety of land owners with diverse goals
- Does not make recommendations
- Menu of adaptation strategies and approaches for forest management
- Online version!



# Adaptation Workbook



# A systematic process...

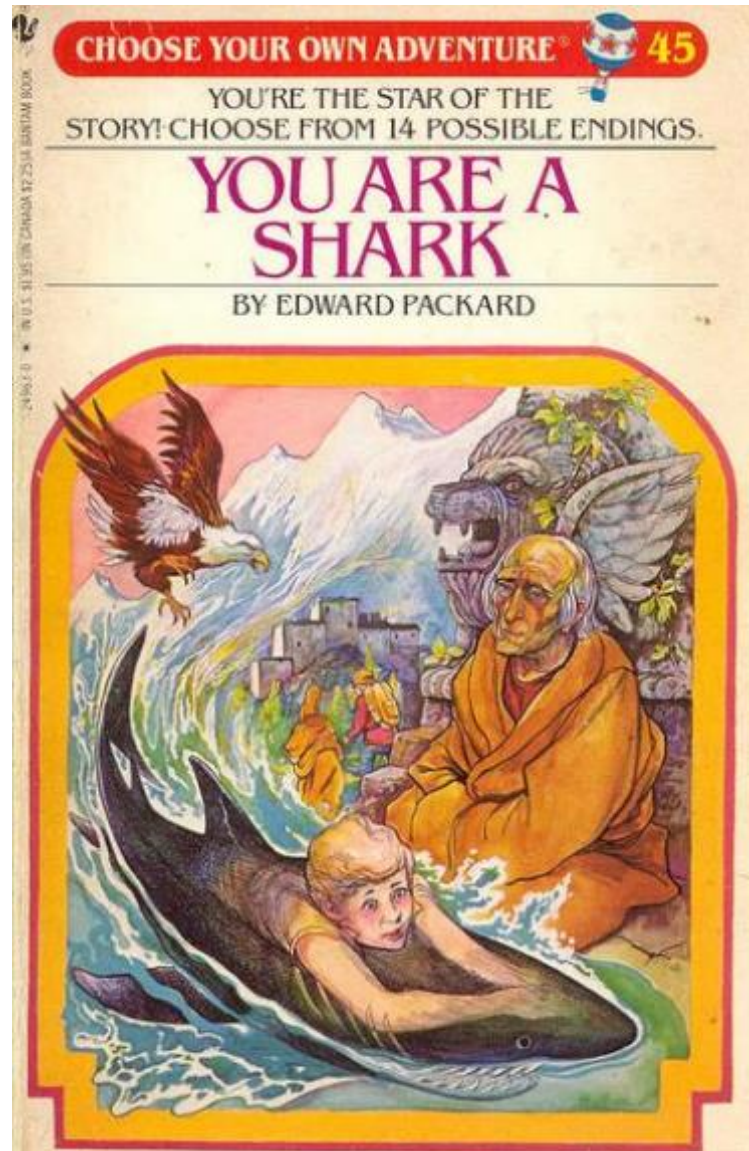
<b>Management Objectives</b>	<b>Challenges</b>	<b>Opportunities</b>	<b>Feasibility</b>	<b>Other Considerations</b>	
<b>Adaptation Actions</b>			<b>Benefits</b>	<b>Drawbacks/ Barriers</b>	<b>Recommend Tactic?</b>
<b>Approach</b>	<b>Tactics</b>	<b>Time Frame</b>			

# Intentional

- Explicitly consider and address climate change
- Sure we might get lucky...
- Intentionally assessing risk and vulnerabilities **makes our plans more robust!**



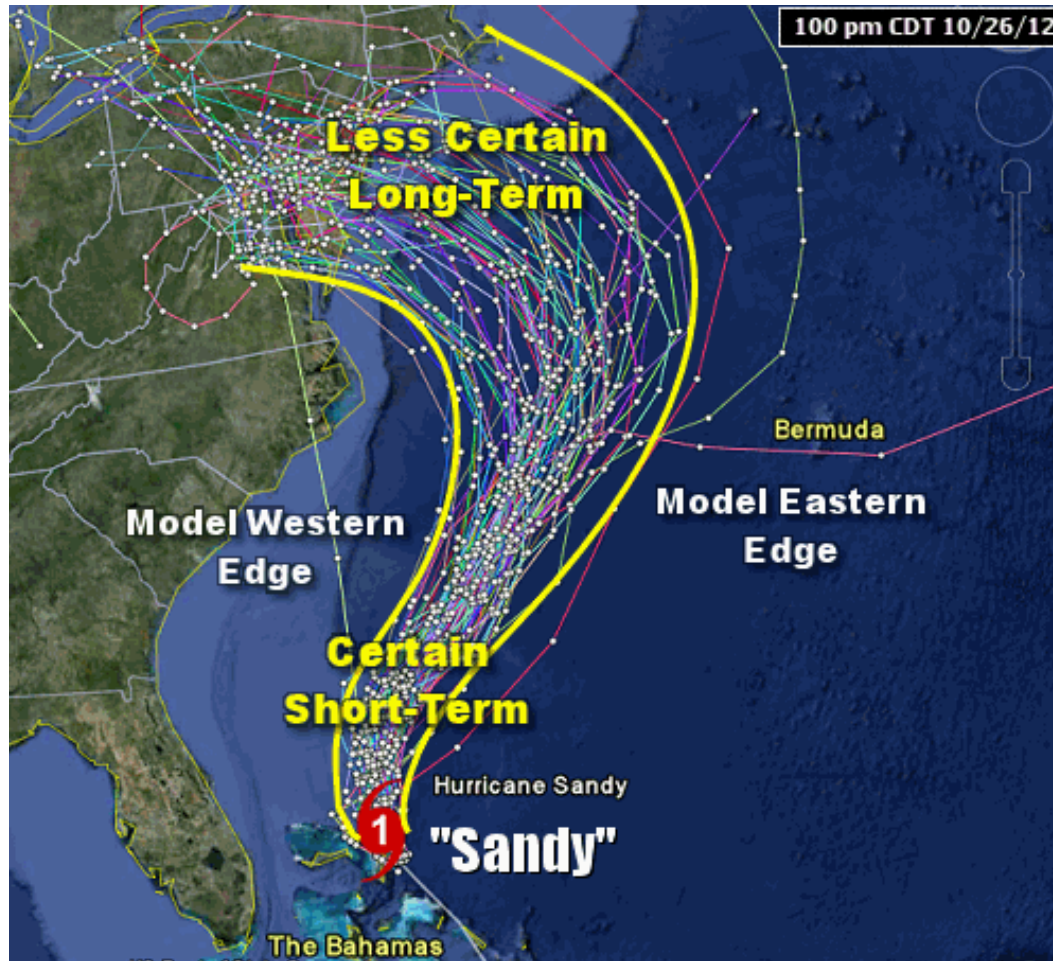
# Flexible



# An Uncertain Future

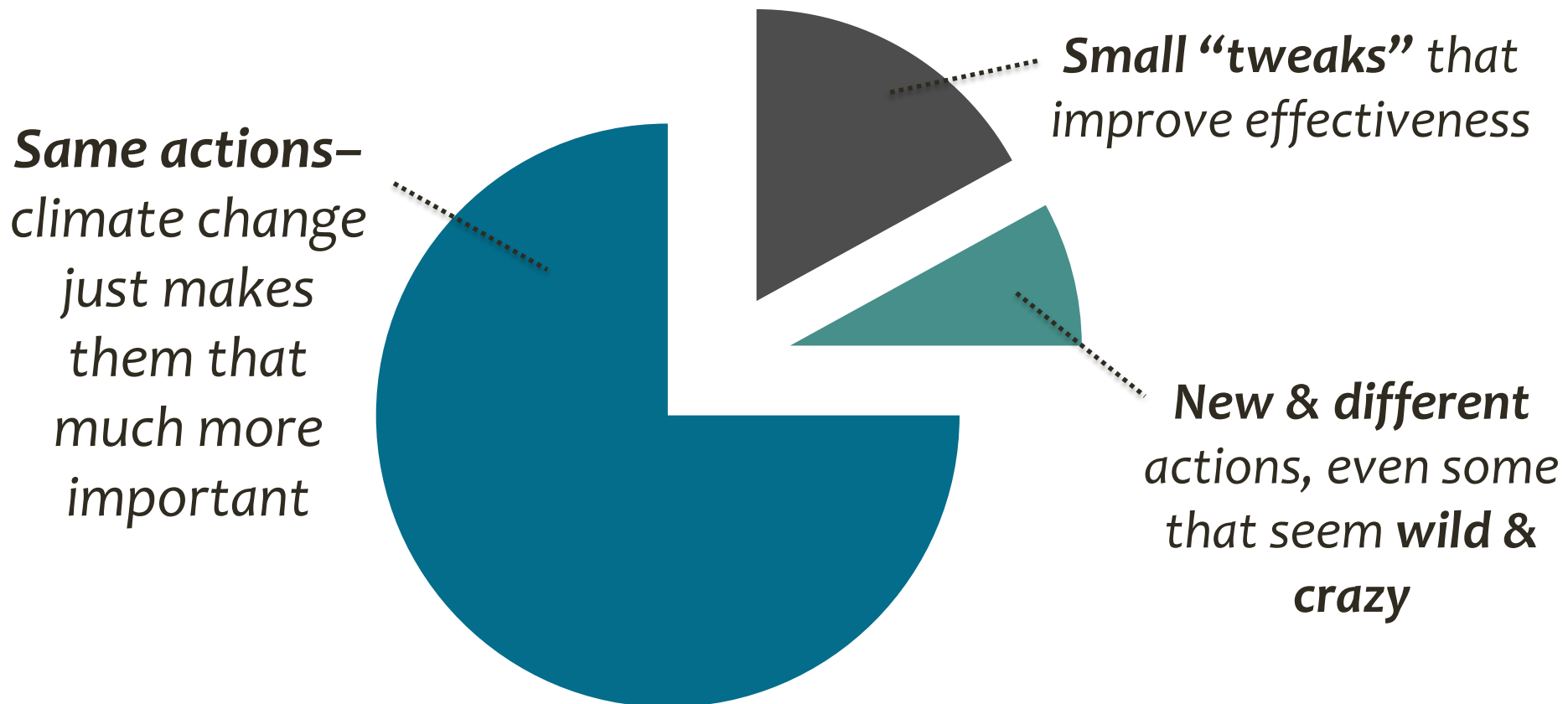
# We Don't Need Certainty

- Instead: think about risk management!

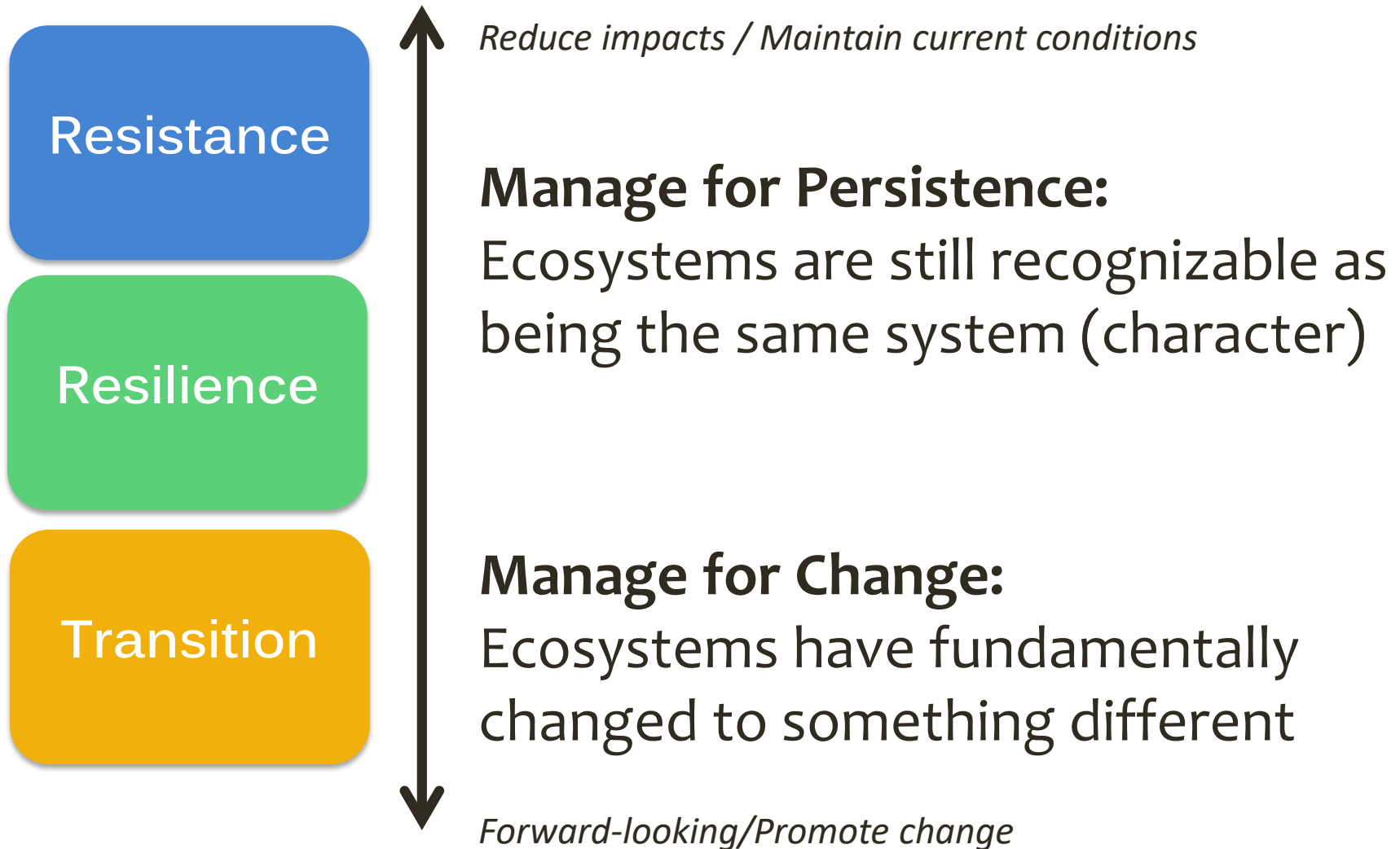


# Adaptation

- Adaptation actions may not look that different from current management actions, especially in the near term.

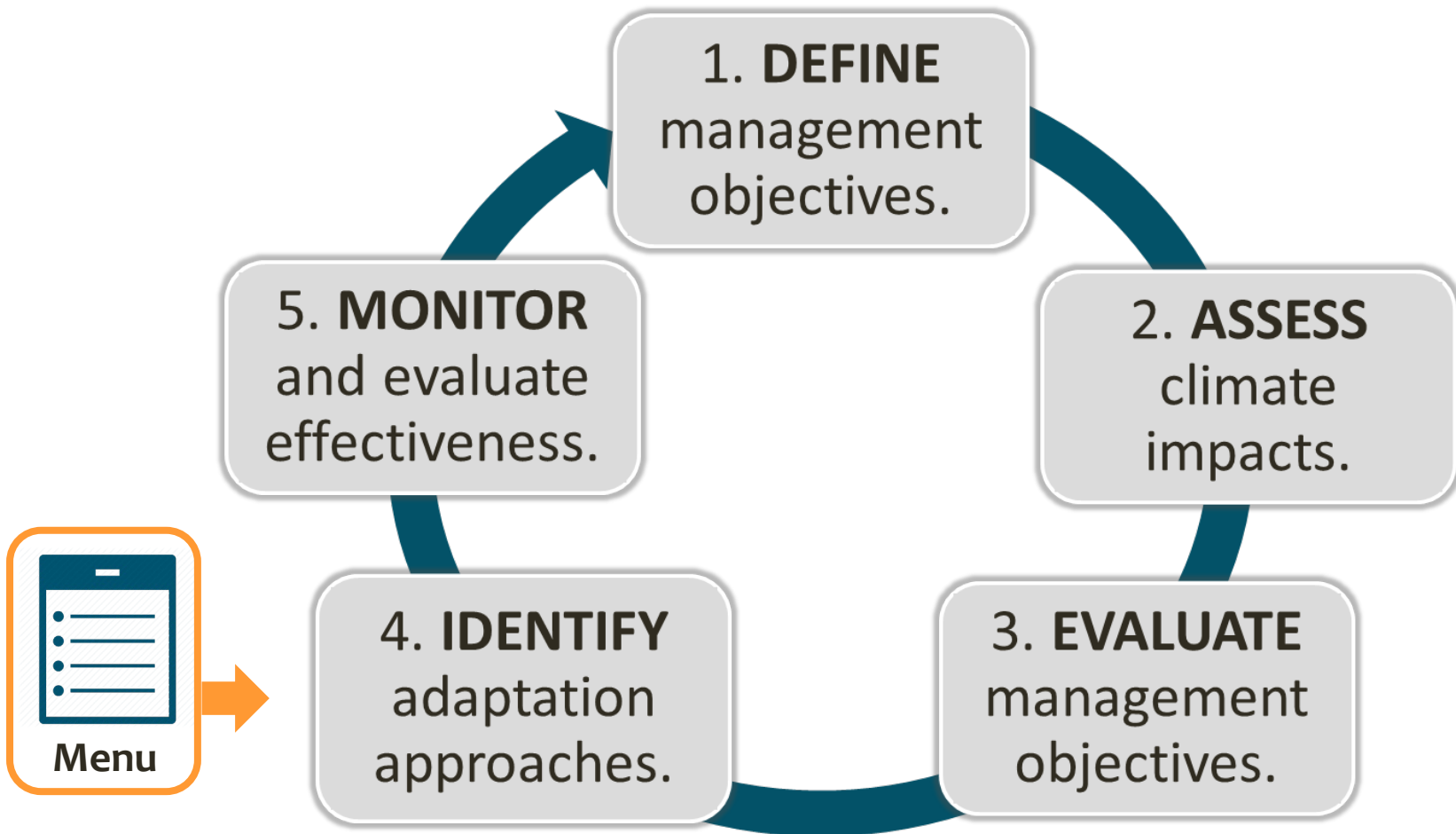


# Adaptation Options



# Adaptation Workbook

*A workbook process provides “structured flexibility”*



# Adaptation Menus

*A collection of plausible adaptation actions that is:*

- Specific to a discipline
- Organized into a tiered hierarchy
- Thorough and comprehensive (including opposing ideas!)

## Brunch Classics

<b>Lemon Ricotta Pancakes</b> Whipped Mascarpone Maple, Berries	15	<b>AJ's Omelet</b> Fontal Cheese, Spinach, Mushrooms	14
<b>Cornflake Crusted French Toast</b> Berries, Maple Syrup	15	<b>Eggs Florentine</b> Spicy Capicola, House-Made Cheddar Biscuit, Spinach	15
<b>Bacon, Egg &amp; Cheese</b> Bacon, Two Eggs, Taleggio Cheese, Ciabatta	14	<b>Porchetta Hash</b> Poached Egg, Calabrian Chili Hollandaise	16
<b>Avocado Toast</b> Poached Eggs, Tomatoes, Chili Flakes, Sea Salt	15	<b>Chia Pudding</b> Chia Seeds, Toasted Coconut, Banana, Strawberry	14
<b>Chicken Parmigiana</b> Spicy Marinara, Fresh Mozzarella	22	<b>Farmhouse Breakfast</b> Two Eggs, House-Made Cheddar Biscuit, Chicken Sausage	14
<b>Squid Ink fettuccine Vongole</b> Little Neck Clams, Garlic, White Wine, Butter, Chili	22	<b>Chicken Kale Caesar</b> Chicken, Kale, Croutons	16

## Create Your Own Pasta

<i>Shapes</i>		<i>Sauces</i>	
<b>Rigatoni</b> Semolina, All-Purpose Flour, Olive Oil	14	<b>Marinara</b> San Marzano tomatoes, Garlic, White Wine, Basil, Chili	
<b>Cavatelli</b> All-Purpose Flour, Durum Flour, Eggs, Ricotta	15	<b>Arrabiata</b> All-Purpose Flour, Durum Flour, Eggs, Ricotta	+1
<b>Tagliatelle</b> All-Purpose Flour, Durum Flour, Eggs	15	<b>Broken Meatball</b> House Tomato Sauce with the Addition of Broken Meatballs	+4
<b>Gluten-Free Rigatoni</b> Gluten-Free All-Purpose Flour, Olive Oil, Eggs	16	<b>Sunday Sauce</b> House Tomato Sauce with Short Rib, Sausage, Veal	+4
<b>Spaghetti</b> Semolina, Durum Flour, Olive Oil	15	<b>Roasted Garlic Pecorino</b> Semolina, Durum Flour, Olive Oil	+2
<b>Four Cheese Herb Ravioli</b> Fontal, Ricotta, Parmesan, Pecorino	18	<b>Carbonara</b> Pancetta, Eggs, Peas, Pecorino	+3

## Sides

Pecorino Truffle Fries	8
Potato Hash	6
Bacon	6
Turkey Sausage	6
Field Greens	7
Two Eggs Any Style	6
Beignets	8
Baked Goods	10



## Brunch Cocktails

<b>Bloody Mary</b> Vodka, Spiced Fresh DOP Tomato Juice, Horseradish	10/45
<b>Cointreau Spritz</b> Cointreau Spritz, Aperol, Crème de Peche, Sparkling Wine	12/55
<b>Green Side</b> Reyka Vodka, Green Juice, Lemon	12/55
<b>Morning Derby</b> Bourbon, Grapefruit, Ginger, Carrot Juice	12/55
<b>Sangria</b> Red Wine, Fresh Fruit, Pisco, Crème de Peche	10/45
<b>Firing Squad</b> Milagros Tequila, Cointreau, Fresh Lime, Grenadine	12/55
<b>Tall Mimosa</b> Reyka Vodka, Cointreau, Jake's Mimosa Juice, Sparkling Wine	12/55

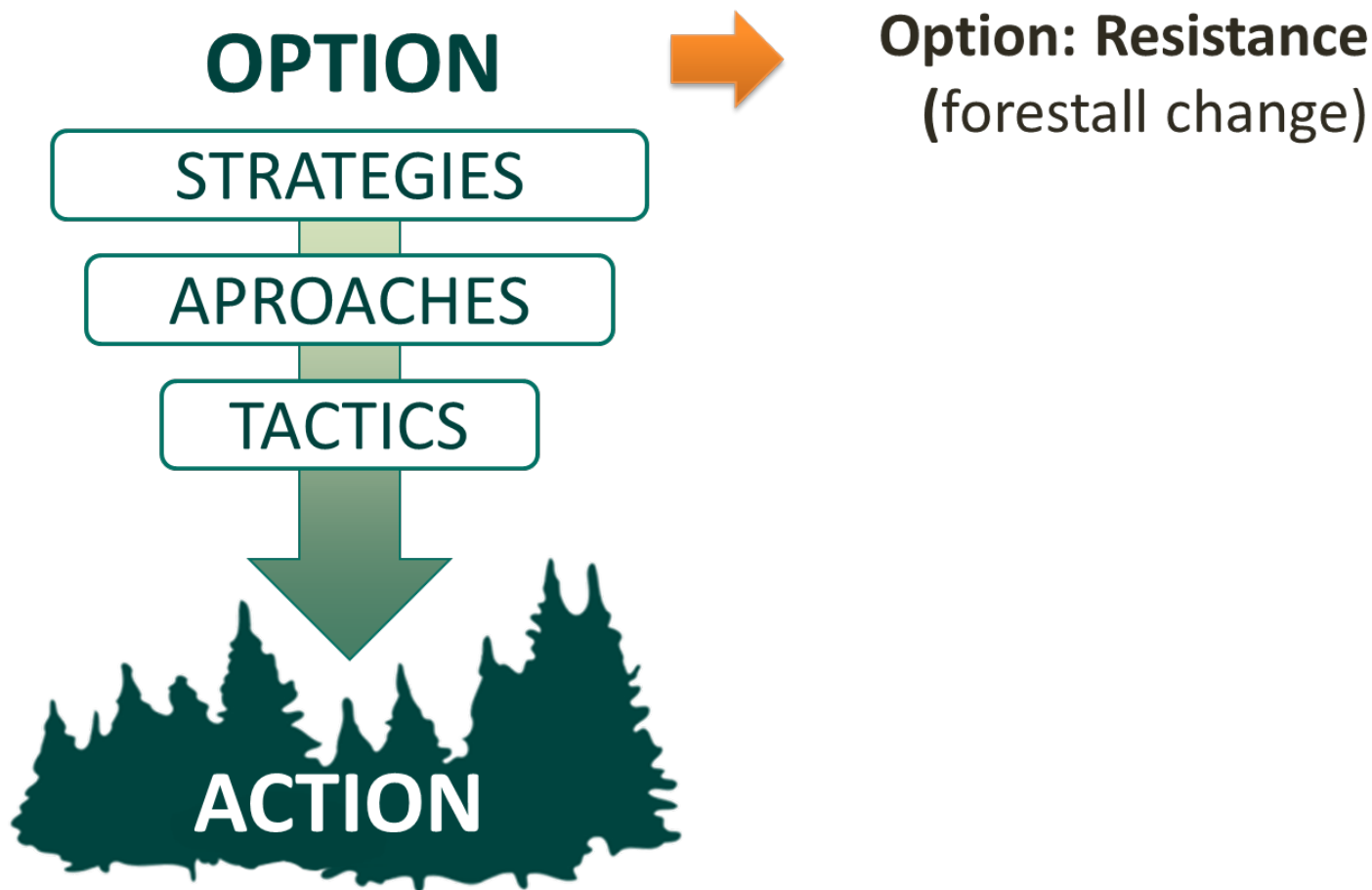
# Adaptation Menu Benefits

## *Address challenges in implementing adaptation:*

1. Connecting broad ideas to specific actions
2. Making actions intentional
3. Communicating your ideas
4. Boosting creativity

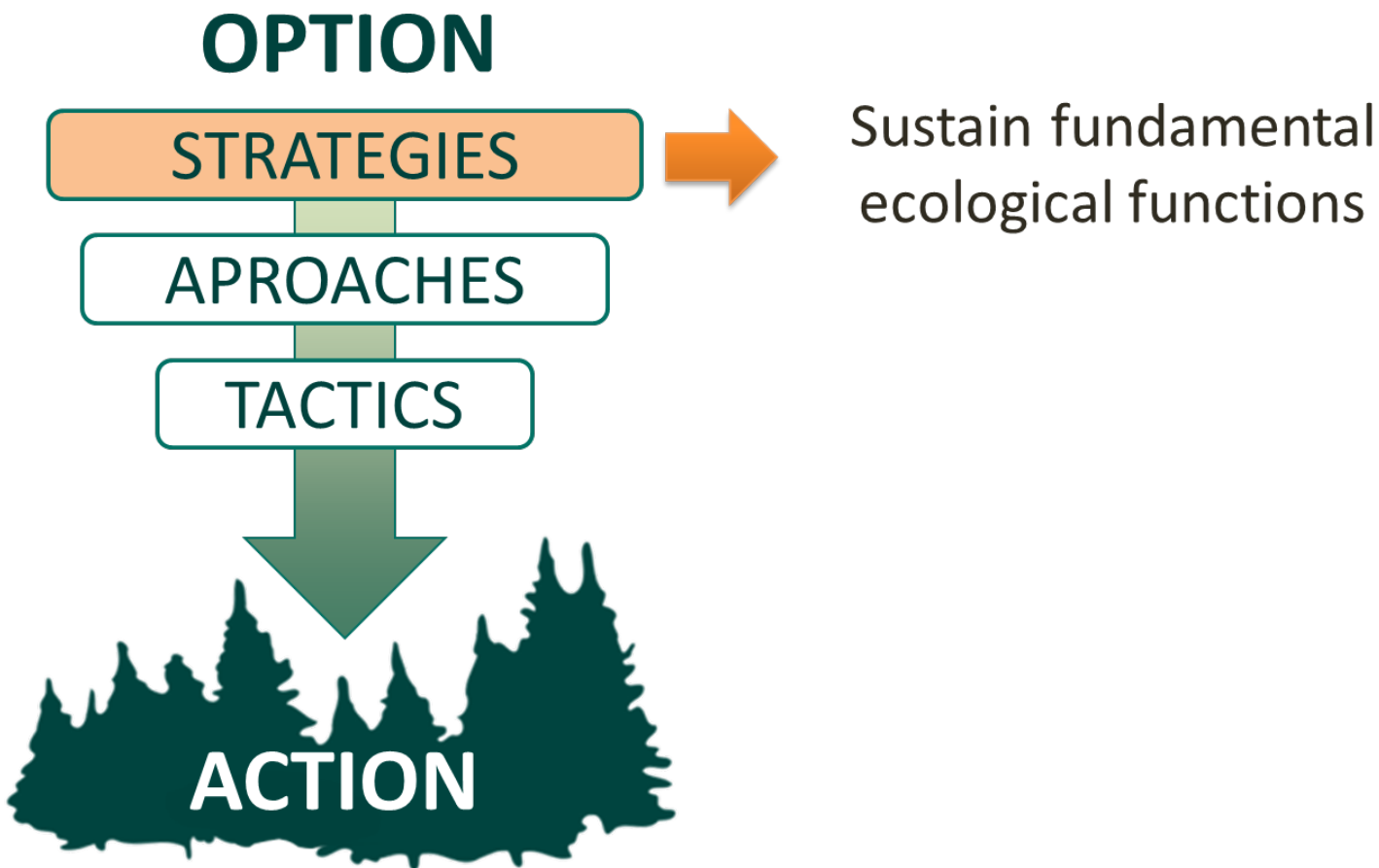
# Adaptation Menus

## 1. *Connecting Broad Ideas to Specific Actions*



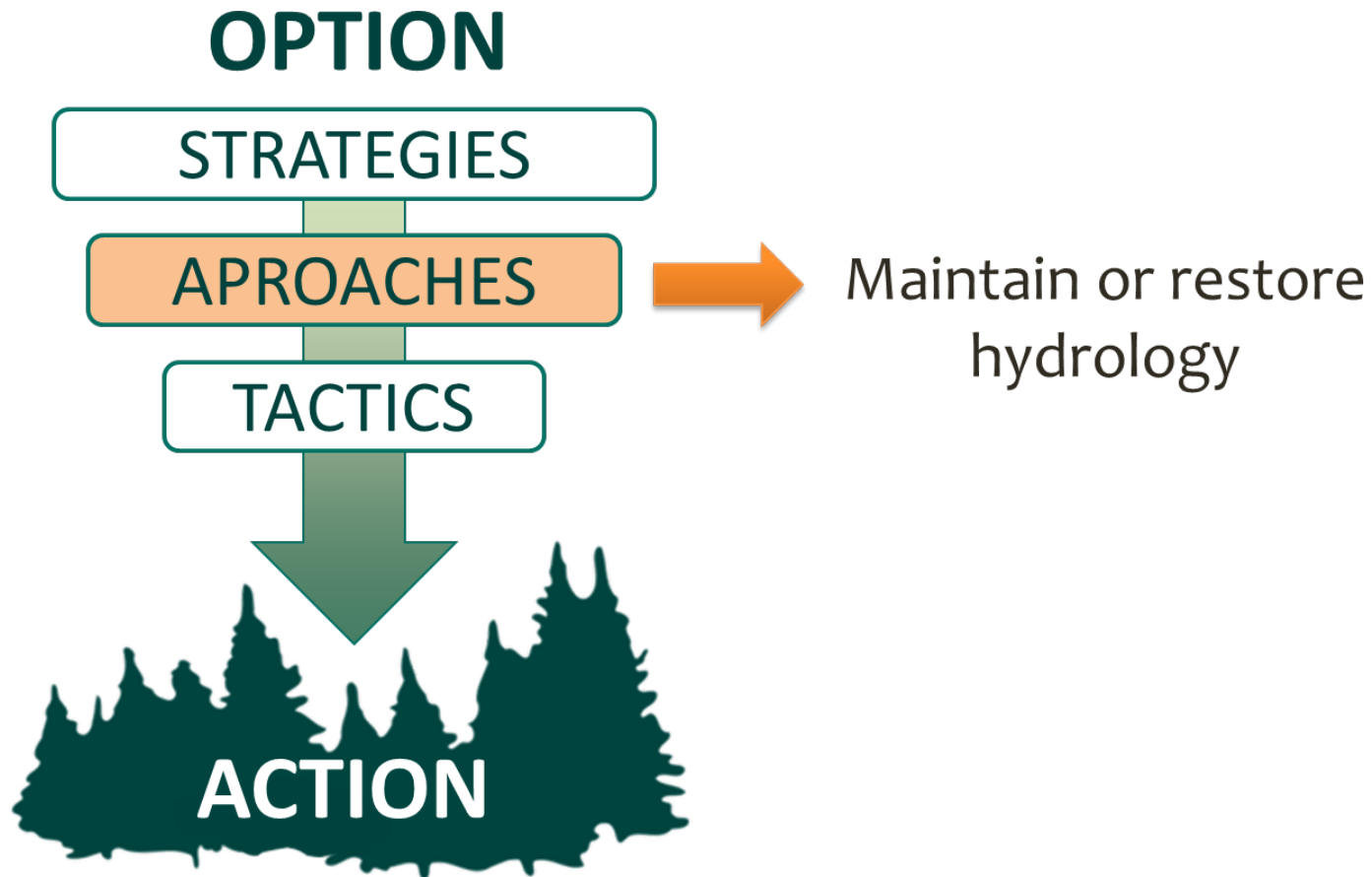
# Adaptation Menus

## 1. *Connecting Broad Ideas to Specific Actions*



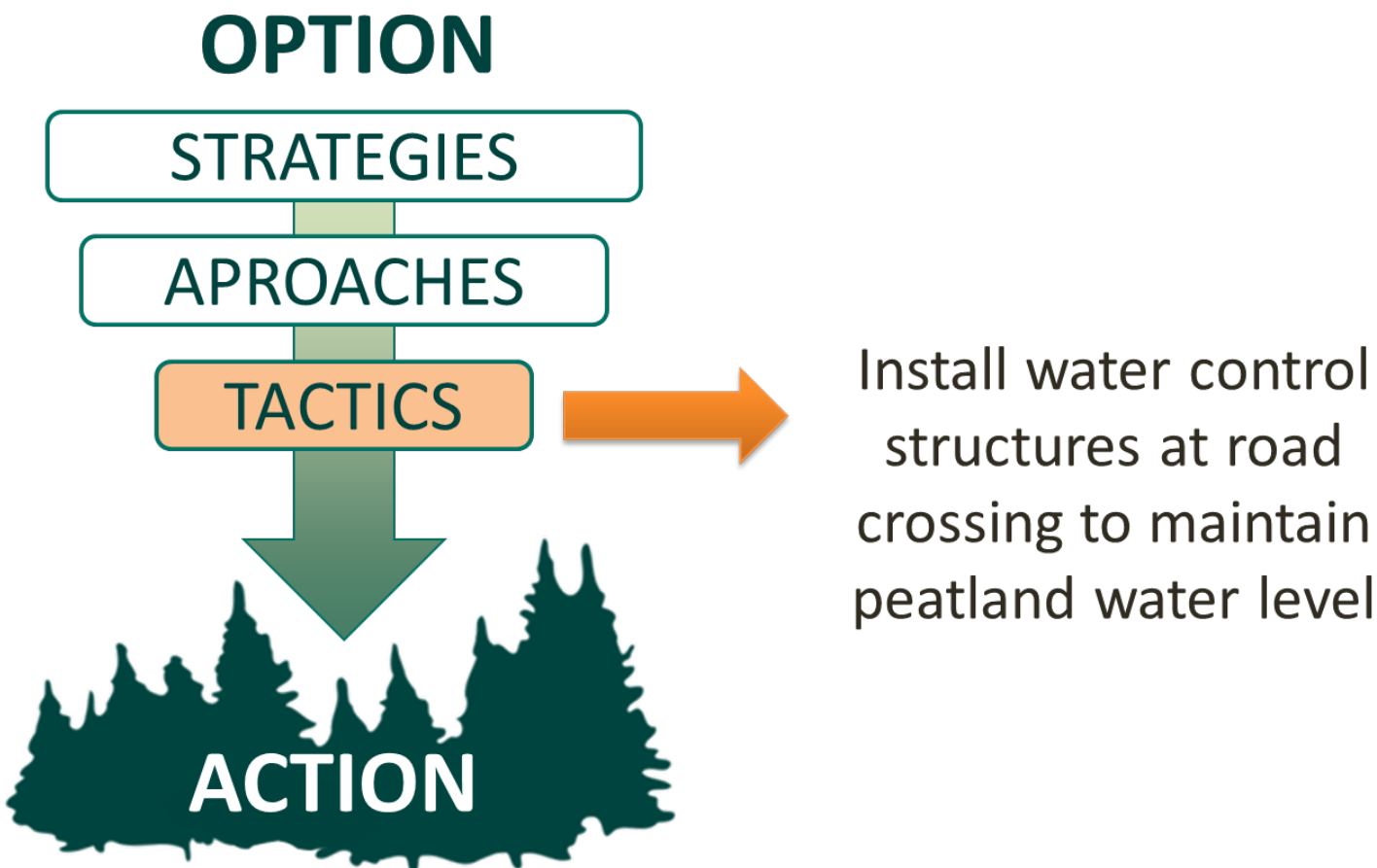
# Adaptation Menus

## 1. *Connecting Broad Ideas to Specific Actions*



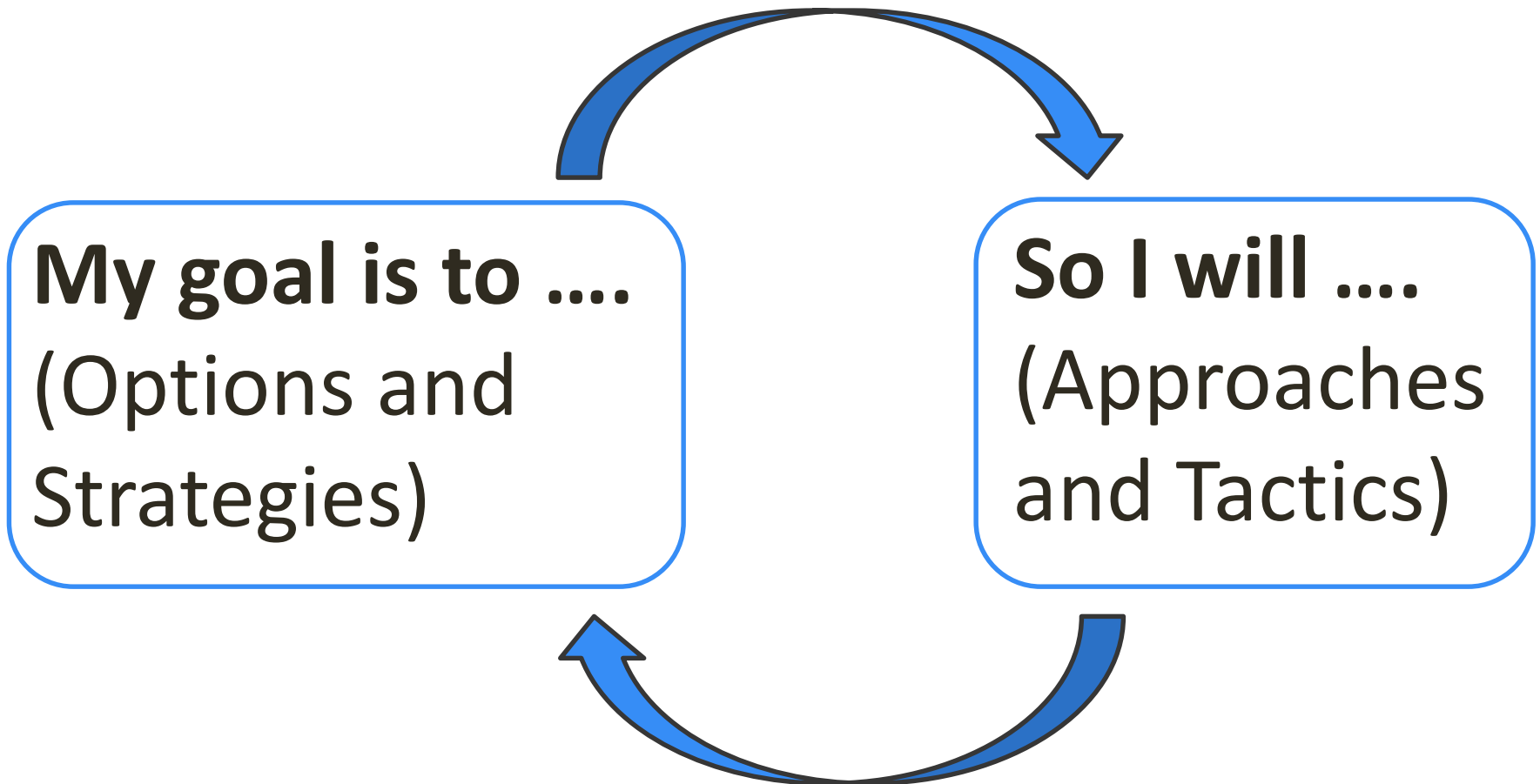
# Adaptation Menu

## 1. *Connecting Broad Ideas to Specific Actions*



# Adaptation Menu

## *2. Making Actions Intentional*



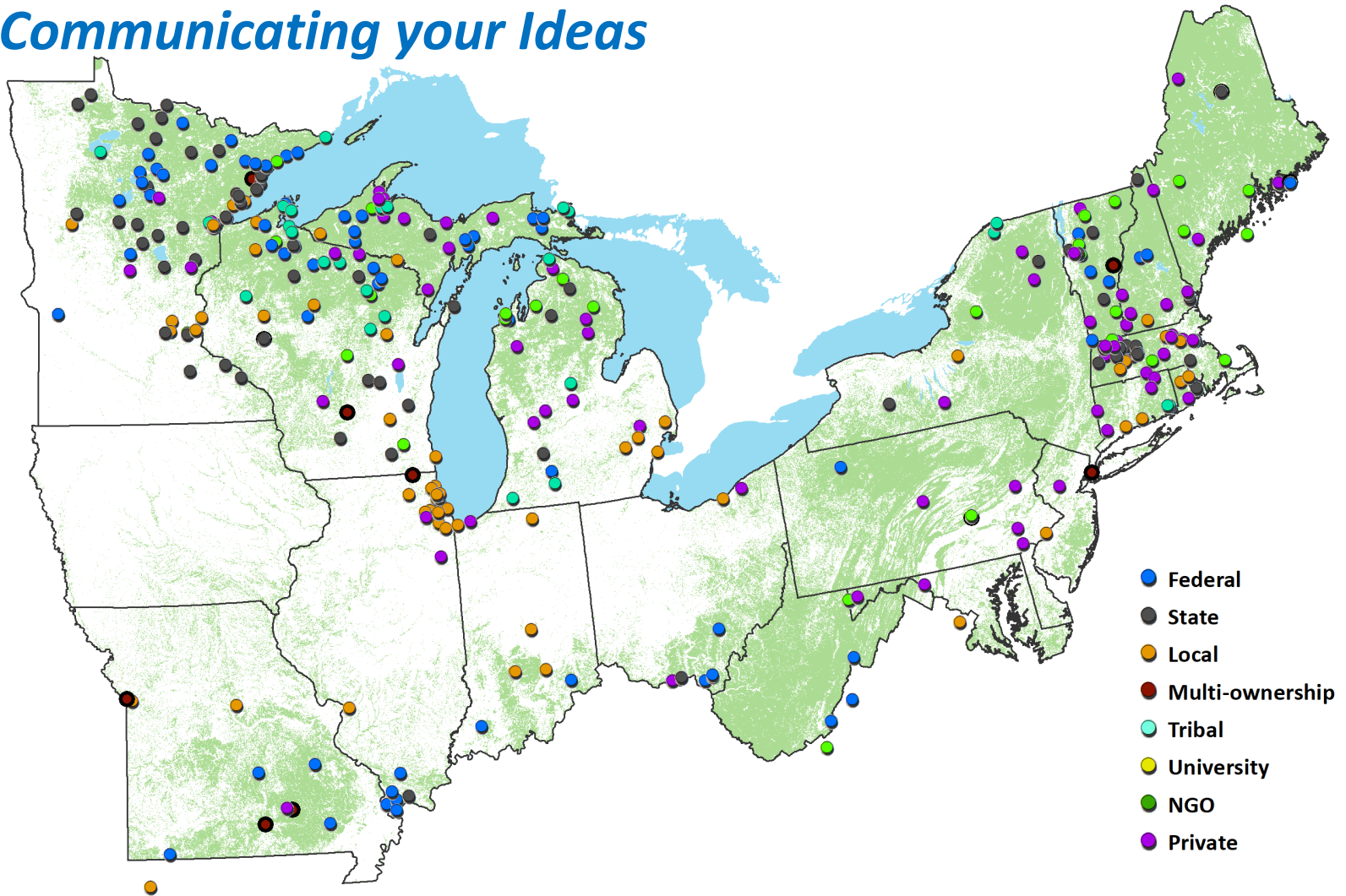
# Adaptation Menus

## 3. Communicating your Ideas



# Adaptation Menu

## 3. Communicating your Ideas



# Adaptation Menus

## *4. Boosting Creativity*



# A Growing Collection

## Published:

- Forestry
- Urban Forestry
- Agriculture
- Forested Wetlands
- Tribal
- Forest Management
- Recreation

- Non-forested Wetlands
- Glacial Lakes Fisheries

## In Preparation:

- Fire (west

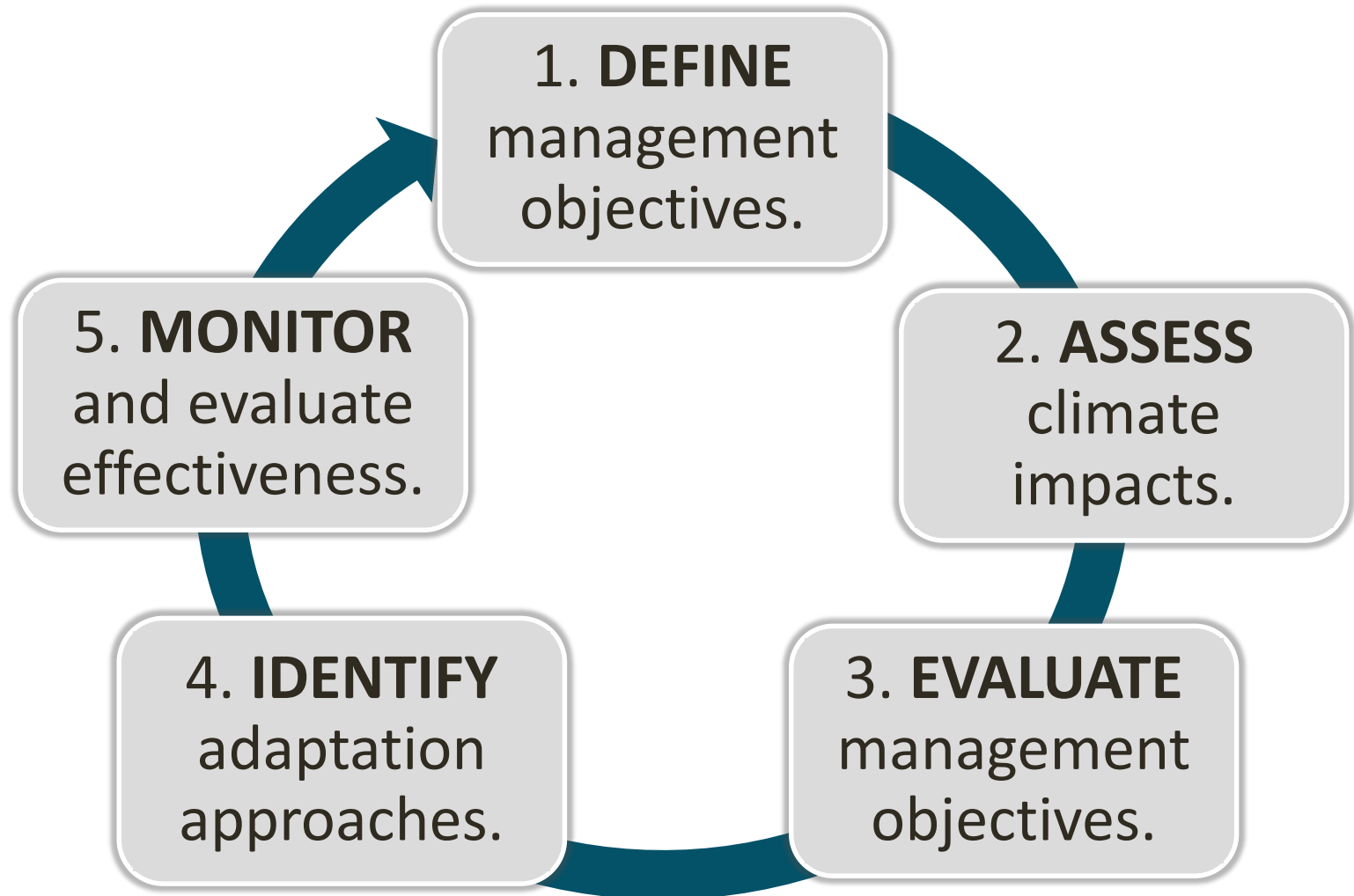
*Mix and Match:*  
Menus can be used independently or together in a single project!



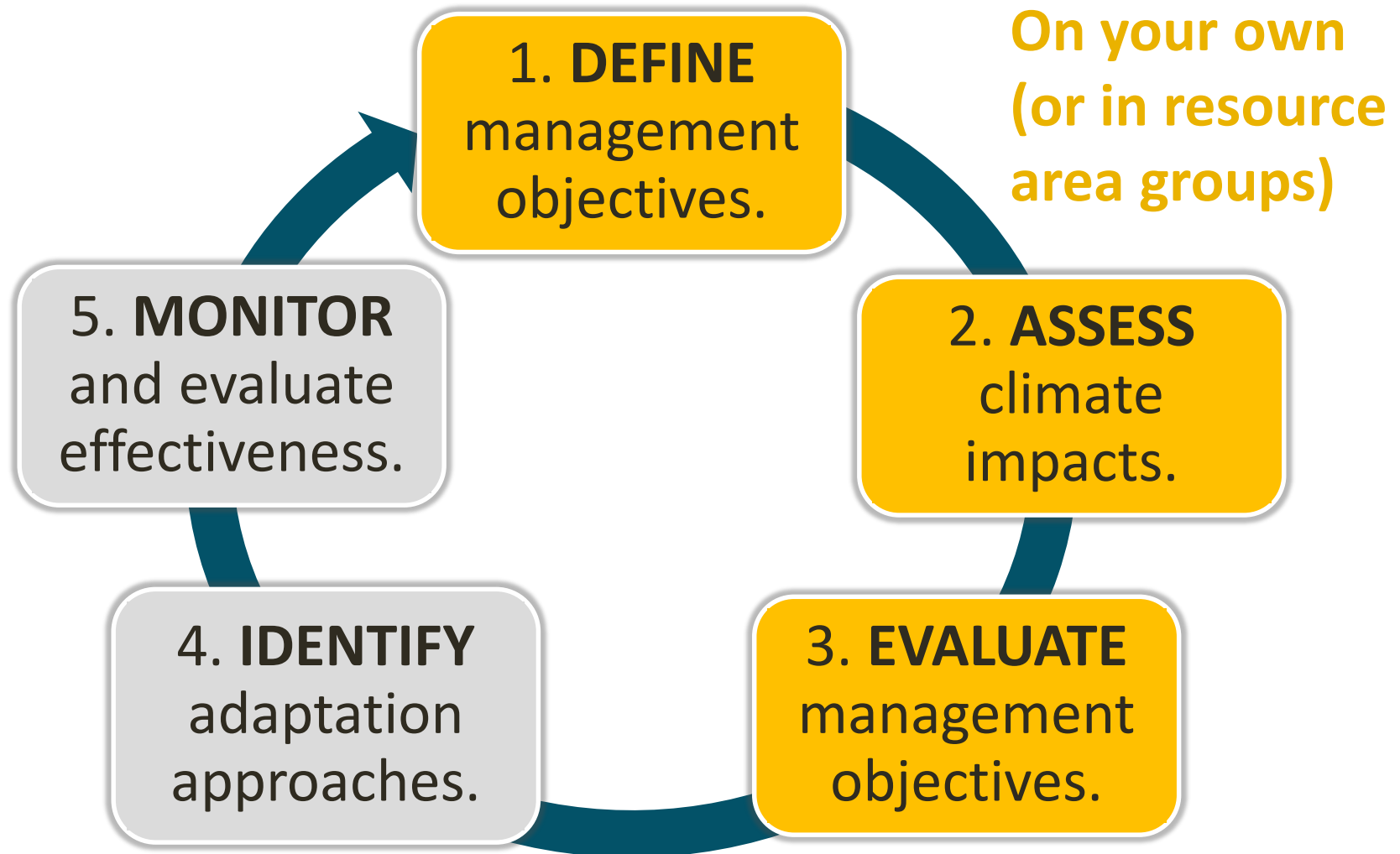
# Gameplan for ASFR



# Adaptation Workbook

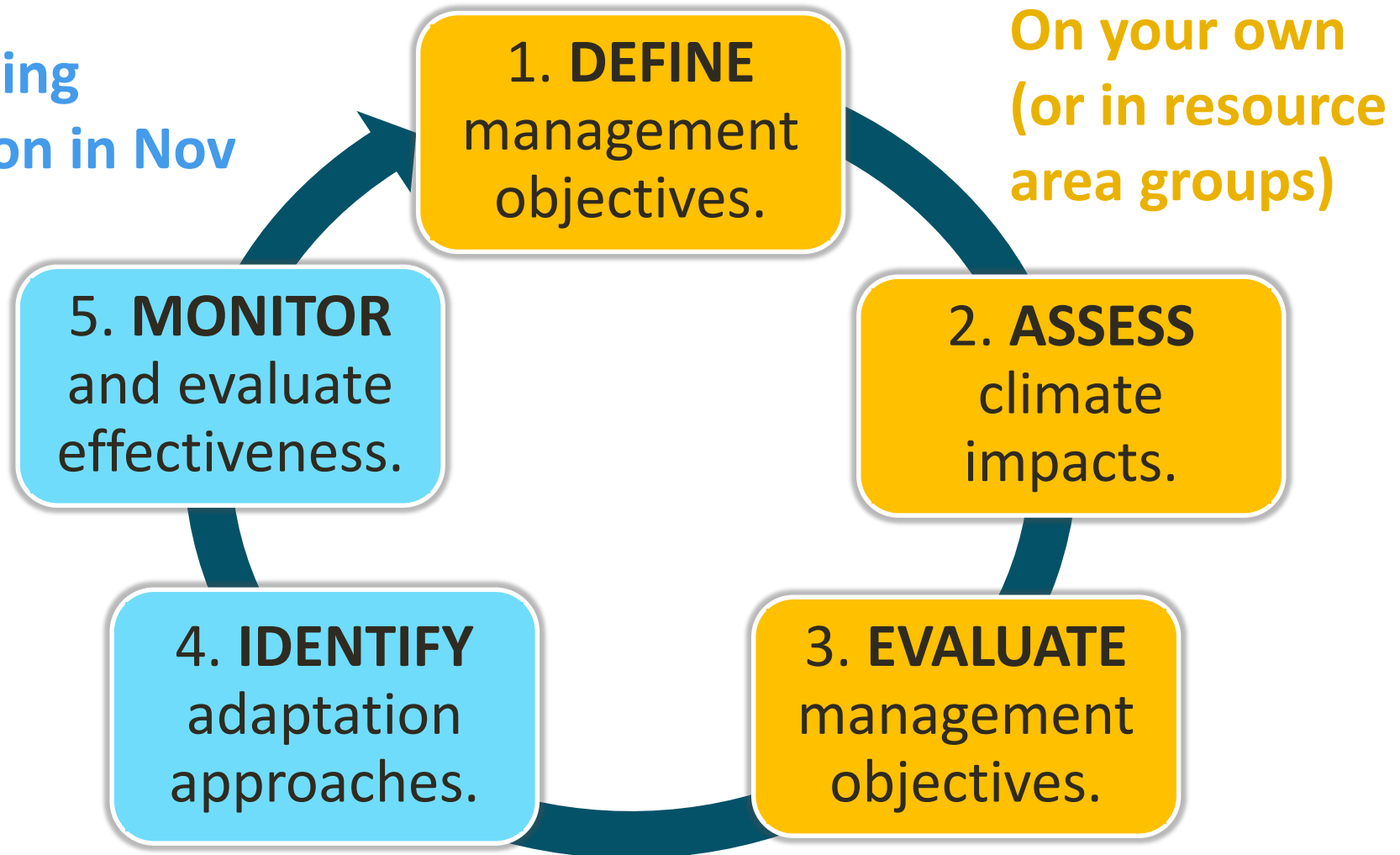


# Adaptation Workbook



# Adaptation Workbook

Working  
Session in Nov



# Step 1 Prep

Write down your key management goals and objectives for your resource area!

Resource Areas	Goals (Made-up examples...)	Objectives
Vegetation/ Silviculture	<ul style="list-style-type: none"><li>• Address the aspen and paper birch “age class bubble” across the district and regenerate young stands</li><li>• Convert aspen to long-lived species in some places</li><li>• Regenerate areas of spruce and fir that have been damaged by spruce budworm or experiencing decline.</li></ul>	<ul style="list-style-type: none"><li>• How/ where/ how much?</li></ul>
Wildlife	<ul style="list-style-type: none"><li>• Increase large white pine for eagle nest sites</li><li>• Prevent brush encroachment into marshes</li><li>• Restore waterfowl habitat and wild rice production within Summit and Cyrus lakes</li></ul>	<ul style="list-style-type: none"><li>• How/ where/ how much?</li></ul>
Water resources	<ul style="list-style-type: none"><li>• Maintain coldwater trout habitat</li><li>• Correct AOP barriers</li></ul>	<ul style="list-style-type: none"><li>• How/ where/ how much?</li></ul>

# Step 2 Prep

1. Which climate change impacts are most important (positive or negative) for your resource area?
2. Are there particular features or conditions within the project area that might increase/decrease climate risk?

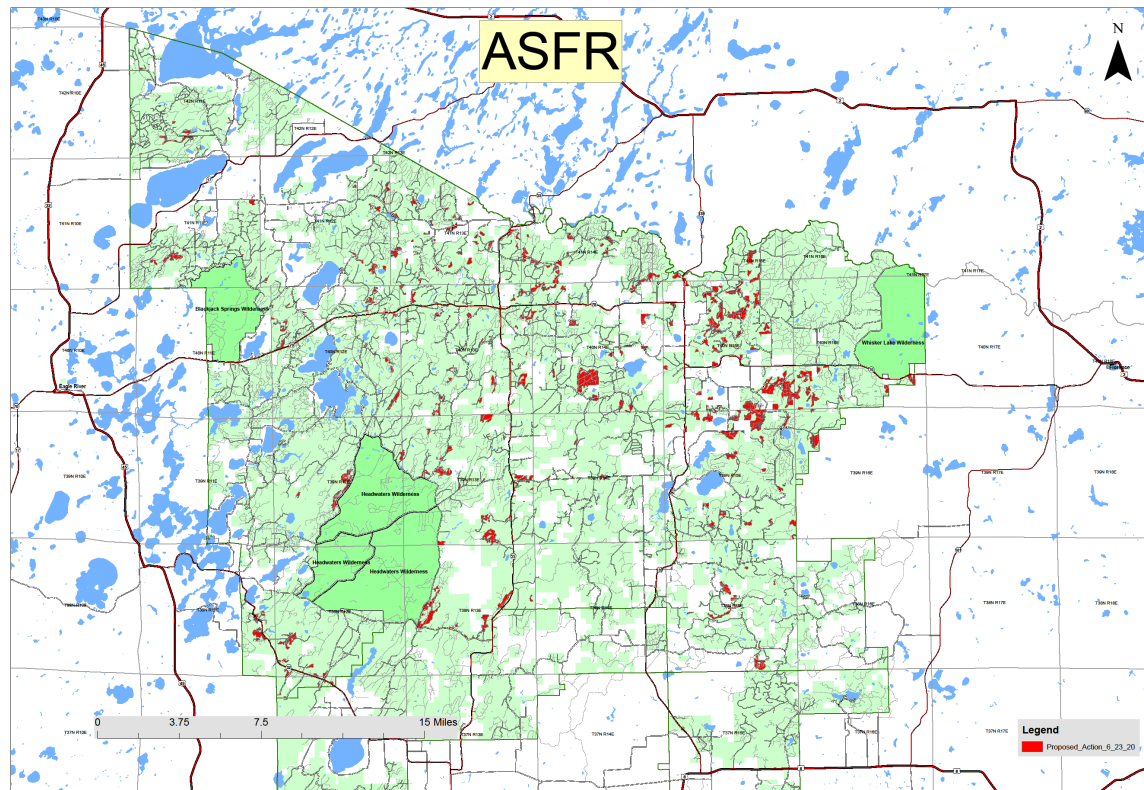
## Step 2. Assess climate change impacts for your Resource Area.

General Climate Change Trends and Projections	Impacts in the Project Area	Points * (20 Total)
<i>General climate change impacts across northern Wisconsin:</i>	<i>Why is this important for your Resource Area? Are there particular features or site conditions in the project area that might increase/decrease risk?</i>	
1. Average temperature increases		
2. Warmer winters (warmer mean temps and greater variance)		
3. Fewer days with extreme cold		
4. Nighttime temperature increases year-round		
5. Decreasing ice cover (Great Lakes and inland lakes)		



# Regional to Site-Specific

- Research and assessments describe broad trends but local conditions and management make the difference.



# Step 3 Prep

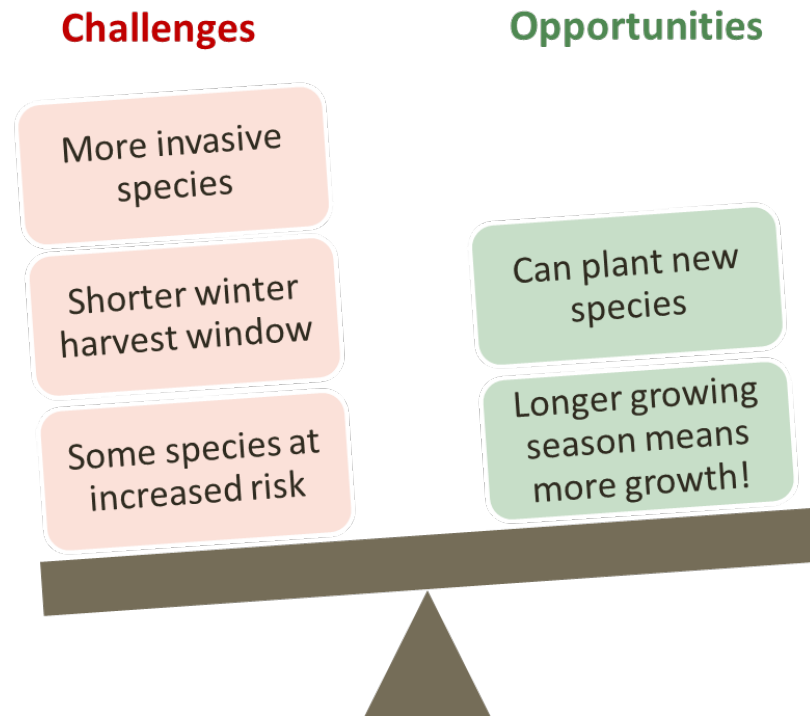
- Evaluate your management objectives (Step 1). Are they still feasible with **current management** (same management tactics, same investment of time and resources)?
- Hold on to these ideas for our discussion.

## *Feasibility definitions:*

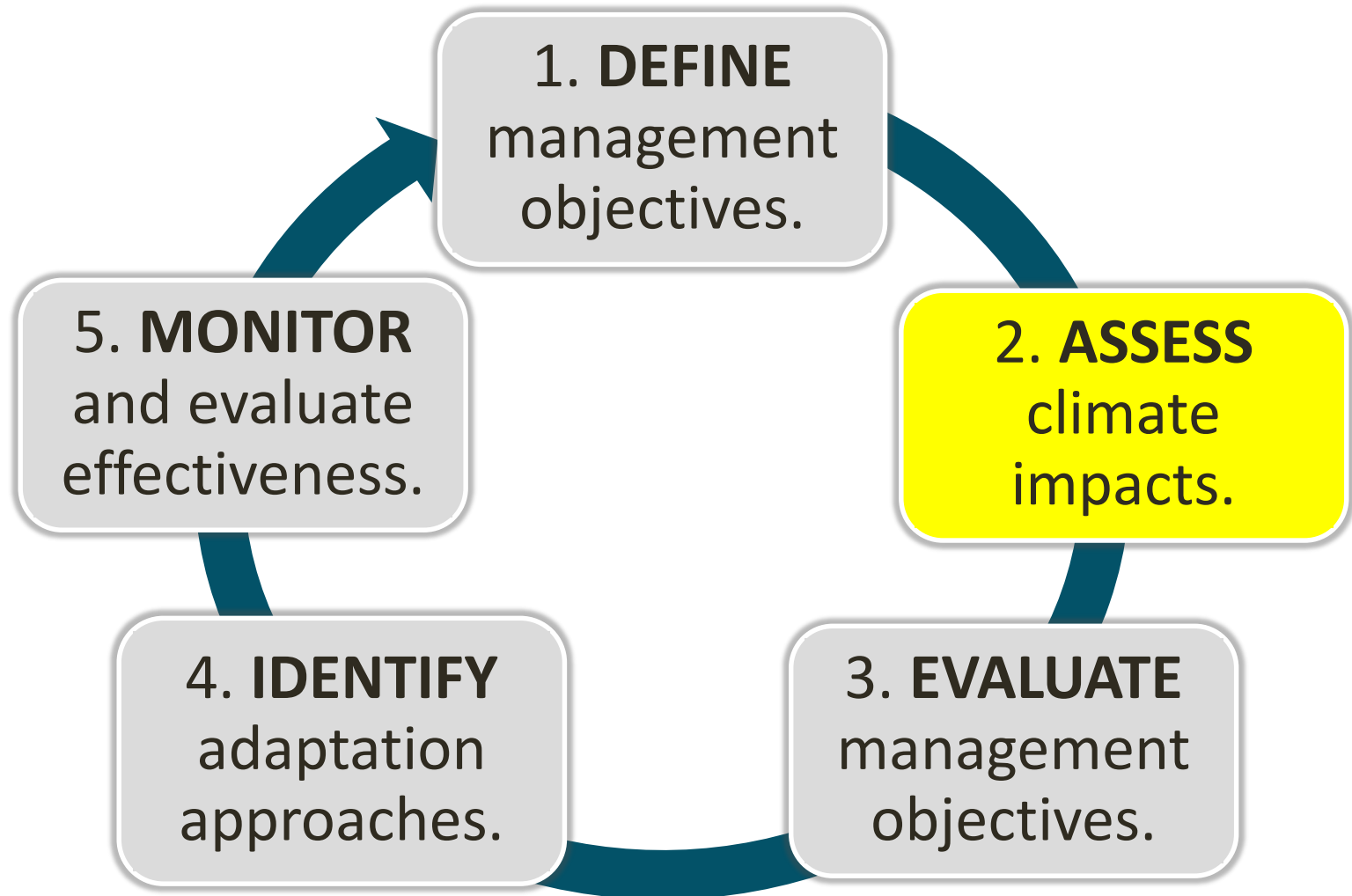
**Low** – Current management may not overcome challenges. Extra resources or new efforts will be necessary.

**Medium** – Current management can likely overcome challenges. Extra resources may be necessary to counteract key challenges or promote new opportunities.

**High** – Current management actions can overcome the challenges presented by climate change. Opportunities outweigh challenges.

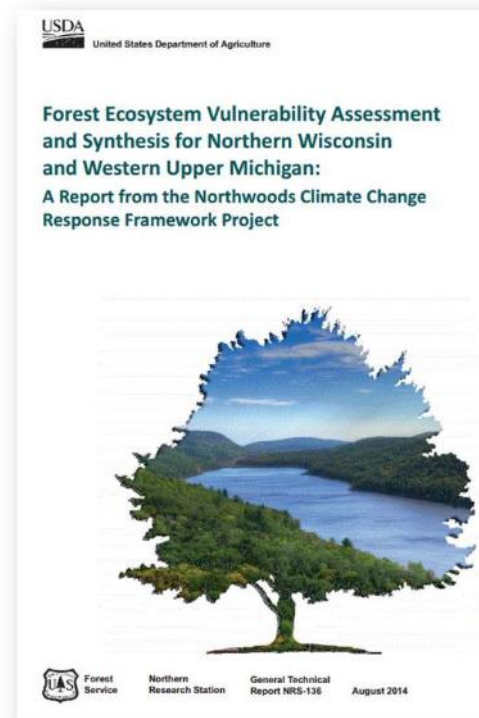


# Adaptation Workbook



# Climate Change Information

- Examine a **range** of future climates
- Do **not** make **recommendations**
- Sources of information:
  - Models
  - Published research
  - Local managers and experts



# More Information

- Climate Change Resource Center



# Even More Information...

## WICCI

- Public website
- Useful handouts
- Natural Community vulnerability assessments
- Links to climate maps, recorded presentations, and other info

The screenshot shows a webpage with a header for the Wisconsin Forestry Working Group (WICCI) and Nelson A. Rockefeller Institute of Government. The main title is "Climate vulnerability assessment: Non-forested wetlands". Below the title is an introduction paragraph. The page is divided into three main sections: "Hydrology", "Invasive and aggressive species", and "Vulnerable species". Each section includes a descriptive paragraph. There are three maps of Wisconsin: one showing annual precipitation change from 1952 to 2018, one showing annual runoff from 1952 to 2018, and one showing annual average daily temperature change from 1952 to 2018. There are also three photographs: a wetland landscape, a field of reed canary grass, and a field of tall grasses. The page is partially obscured by a red sidebar on the right with the text "CONTACT US" and "TACT IS".

**Climate vulnerability assessment: Non-forested wetlands**

Introduction: Climate change may bring higher temperatures, variable precipitation, and more frequent intense storms. This document provides a broad summary of potential impacts of climate change, and may provide a foundation for conservation planning in the face of an uncertain future.

**Hydrology**  
Altered hydrology is the greatest anticipated impact to non-forested wetlands from climate change. The likelihood of more extreme precipitation events increases the risk of erosion and sedimentation as well as nutrient runoff, which can fuel the transportation and growth of non-native invasive plants and weedy native species. The impact of these events is likely to be greatest lower in the watershed, where flood waters collect for a longer period of time. In addition, winter temperature and precipitation

**Invasive and aggressive species**  
Non-native invasive species are already a problem in many natural communities, especially in southern Wisconsin. Longer growing seasons disproportionately benefit invasives like reed canary grass, which can continue growing longer in the fall than native grasses and sedges. In addition, sedimentation and excess nutrients favor species like non-native cattail and Phragmites. Elevated levels of CO<sub>2</sub> may favor woody species, including invasive shrubs like glossy buckthorn. In general, non-native invasives species respond well to rapid environmental changes, including extreme storms, which can disturb soil and spread propagules.

**Vulnerable species**  
With a few exceptions, many dominant non-forested wetland plants in Wisconsin also occur well to the south, indicating they may be less sensitive to changes in temperature than to changes in the delicate balance in hydrologic regimes and nutrients. Those species that may be most vulnerable tend to be associated with communities that occur at the southern edge of their range in Wisconsin, such as Boreal Rich Fen, Shore Fen and, in the southern part of the state, Bog Relict and Alder Thicket.

Runoff from large rain events carries sediments and excess nutrients into wetlands.

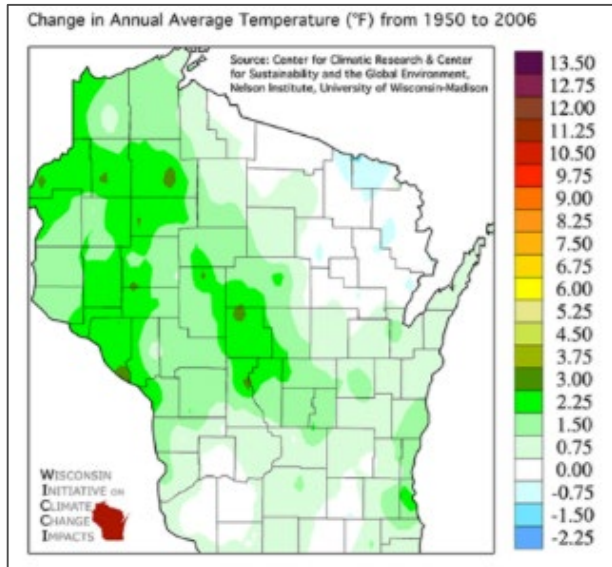
Longer growing seasons could benefit invasive species like reed canary grass.

Historical Change in Annual PPT from 1952 to 2018  
Change in annual precipitation (mm)

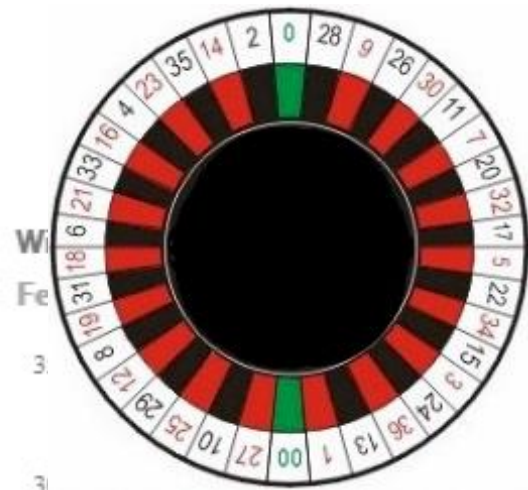
Historical Change in Annual Runoff from 1952 to 2018  
Change in annual runoff (mm)

Historical Change in Annual Average Daily Temperature from 1952 to 2018  
Change in annual average daily temperature (°C)

# Climate vs. Weather



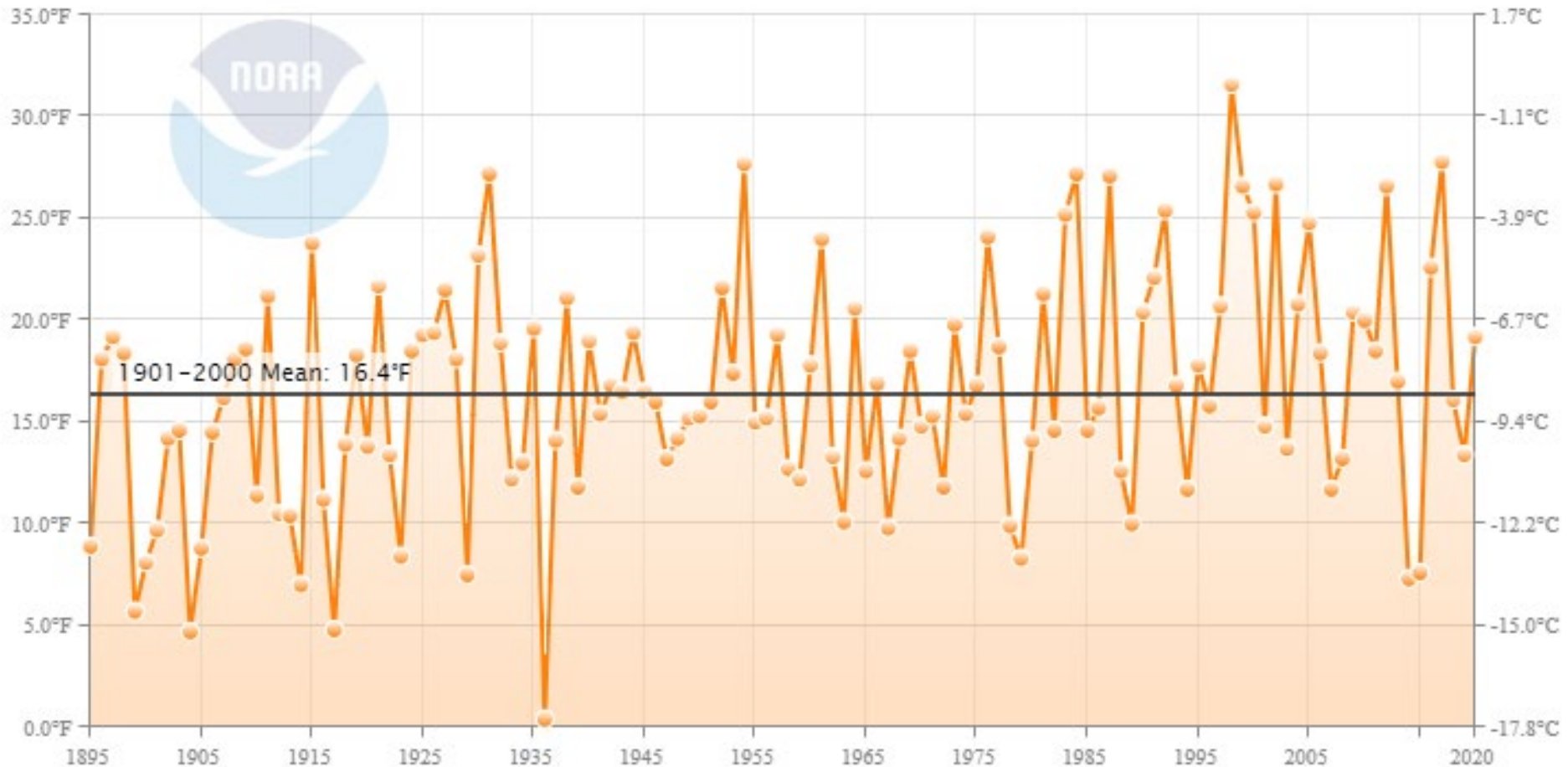
# Weather



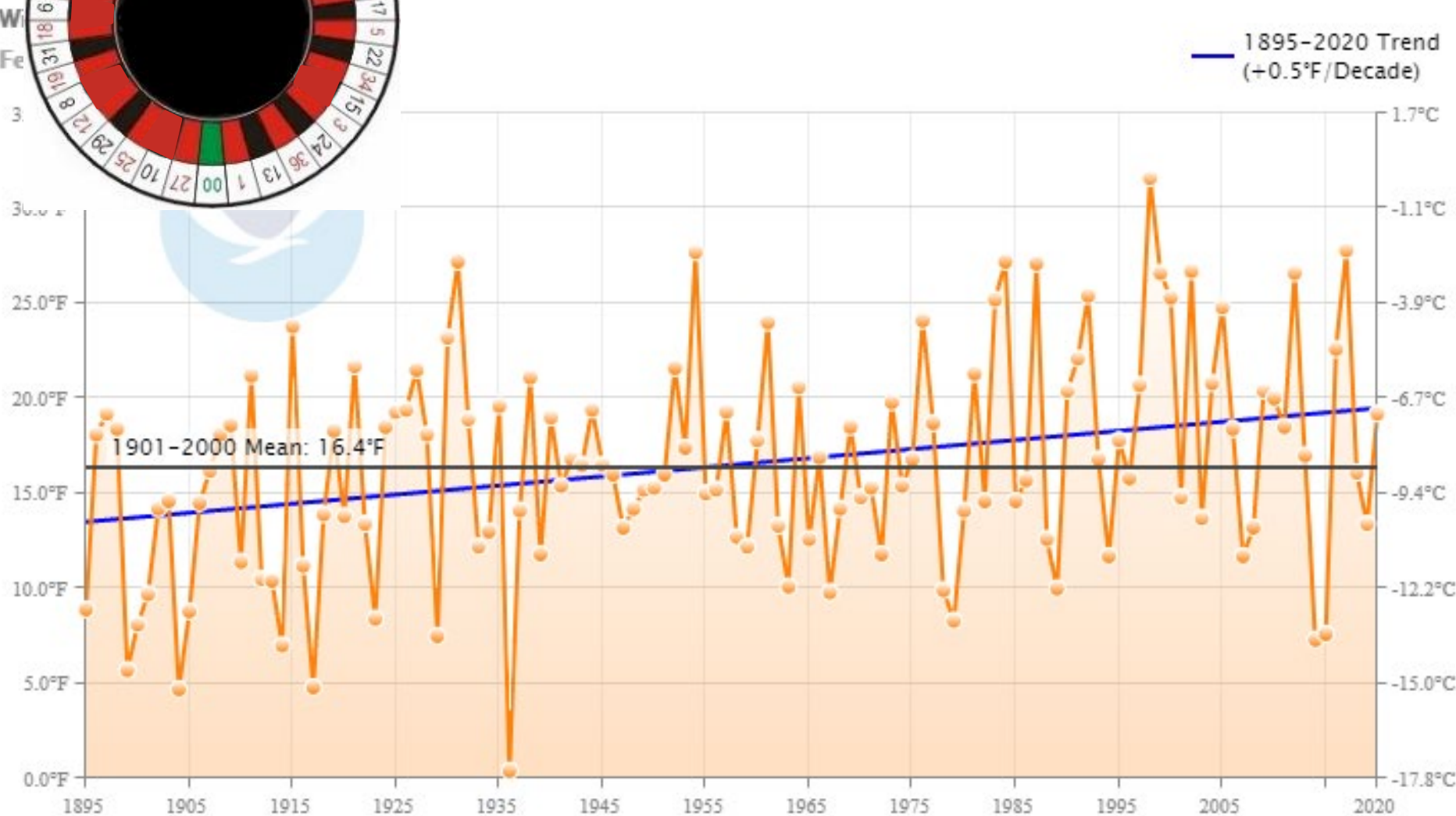
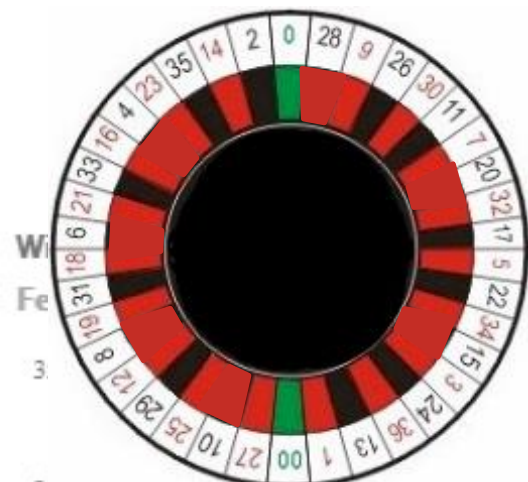
# Weather + Time = Climate

Wisconsin Average Temperature

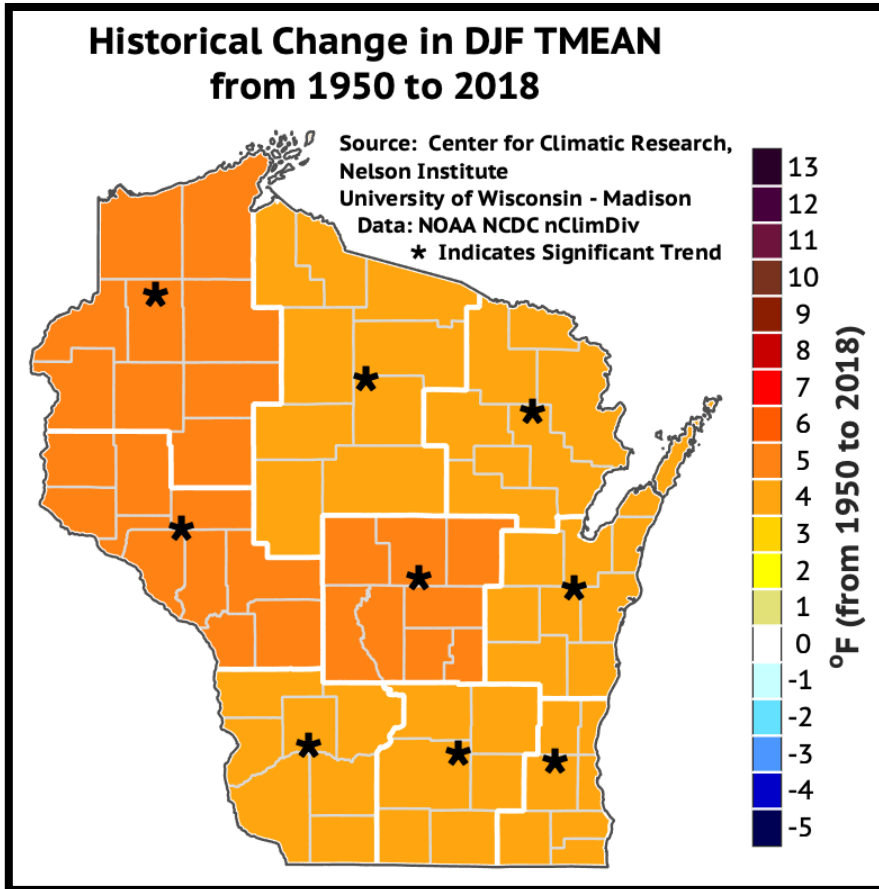
February



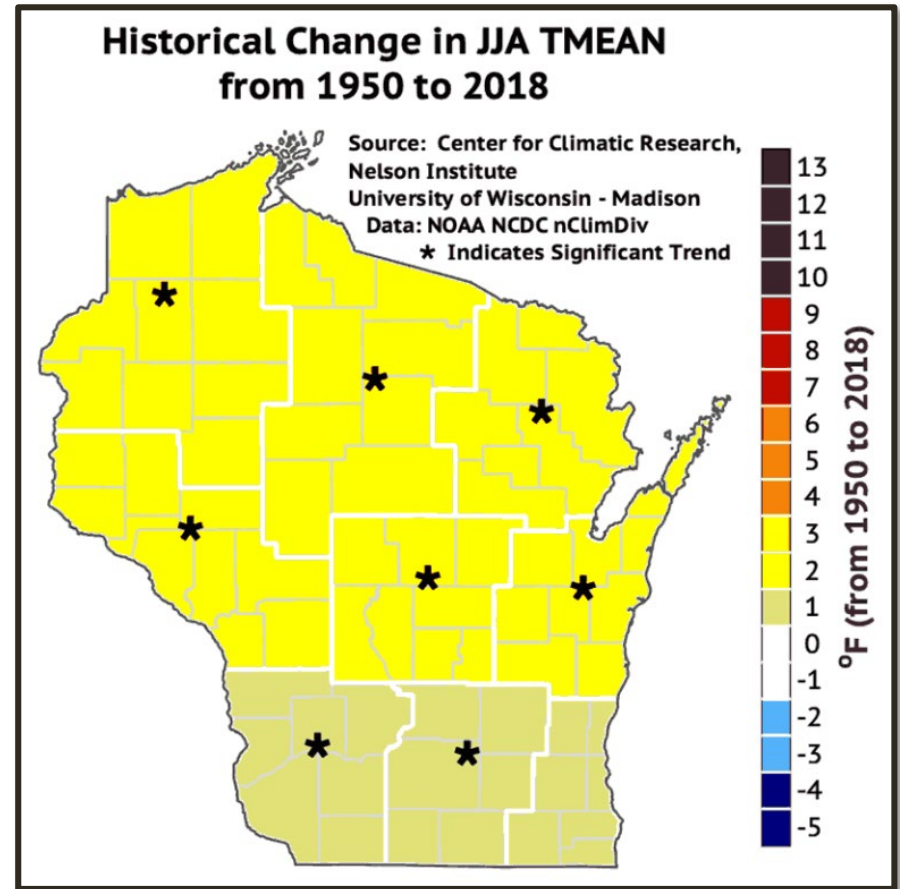
# Climate Change



# Temperature Change - Observed



Winter



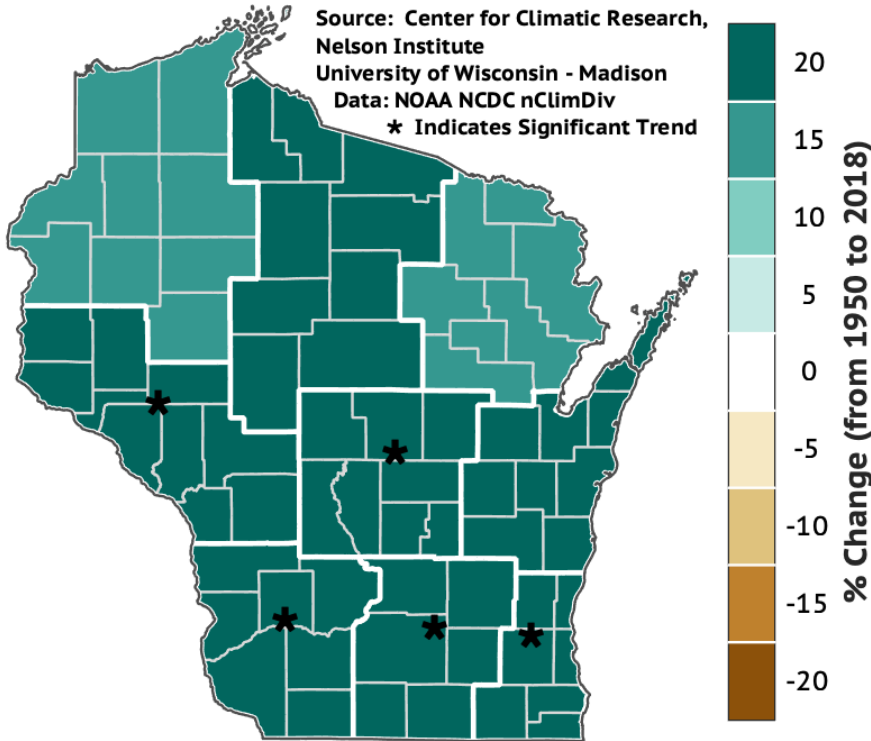
Summer



# Precipitation Change - Observed

## Historical Change in DJF PRECIP (%) from 1950 to 2018

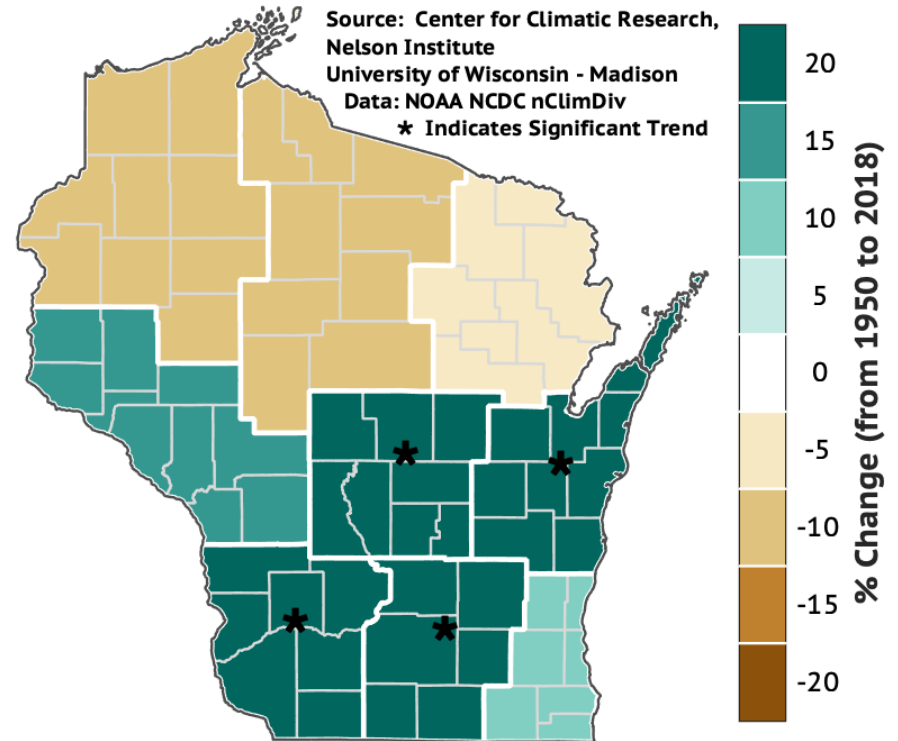
Source: Center for Climatic Research,  
Nelson Institute  
University of Wisconsin - Madison  
Data: NOAA NCDC nClimDiv  
★ Indicates Significant Trend



Winter

## Historical Change in JJA PRECIP (%) from 1950 to 2018

Source: Center for Climatic Research,  
Nelson Institute  
University of Wisconsin - Madison  
Data: NOAA NCDC nClimDiv  
★ Indicates Significant Trend



Summer

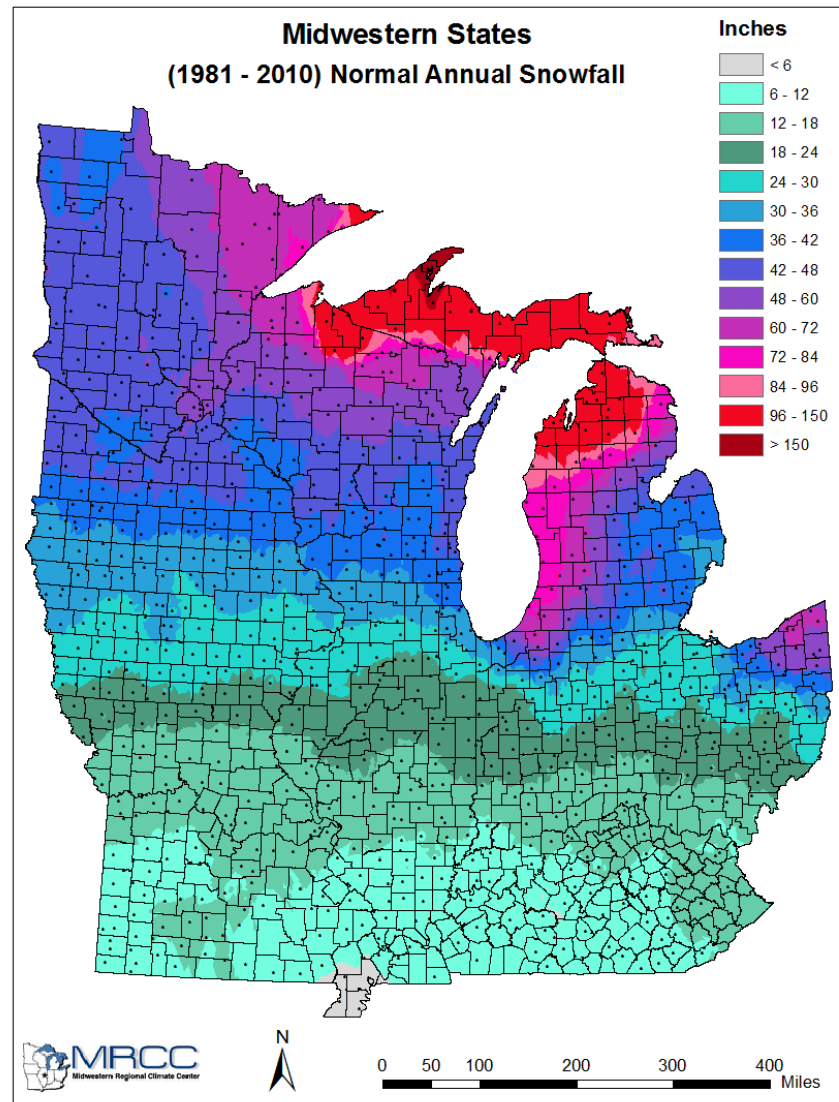
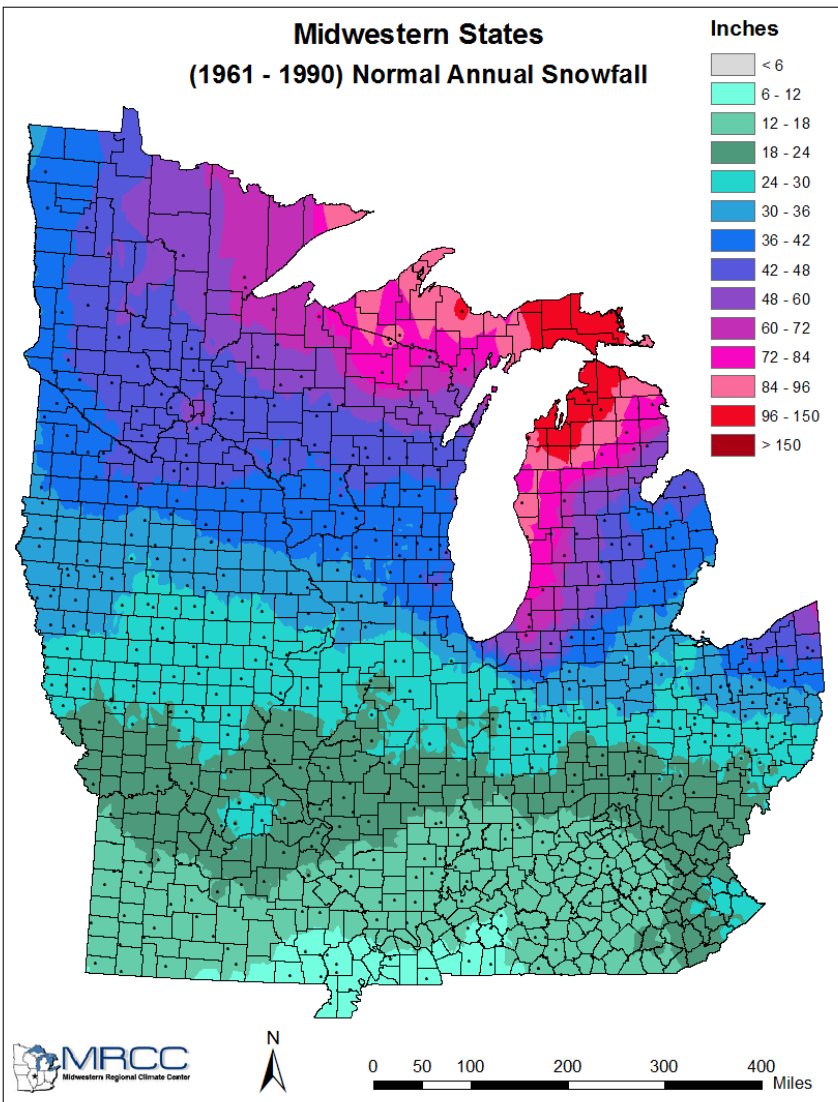


# Heavy Precipitation - Observed

- Large rain events (3"+) have become more frequent



# Snowfall - Observed



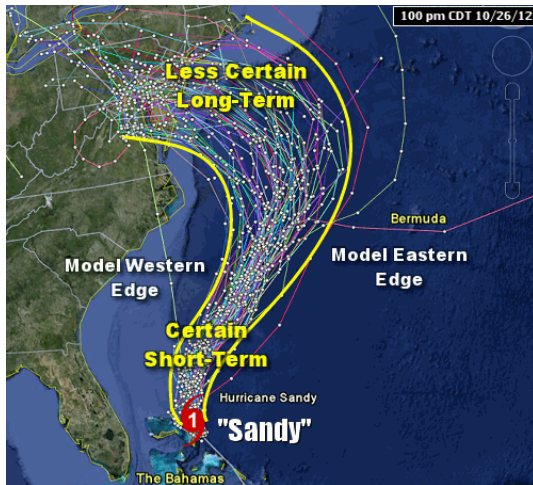
(Midwestern Regional Climate Center)

# *Future Climate Projections*

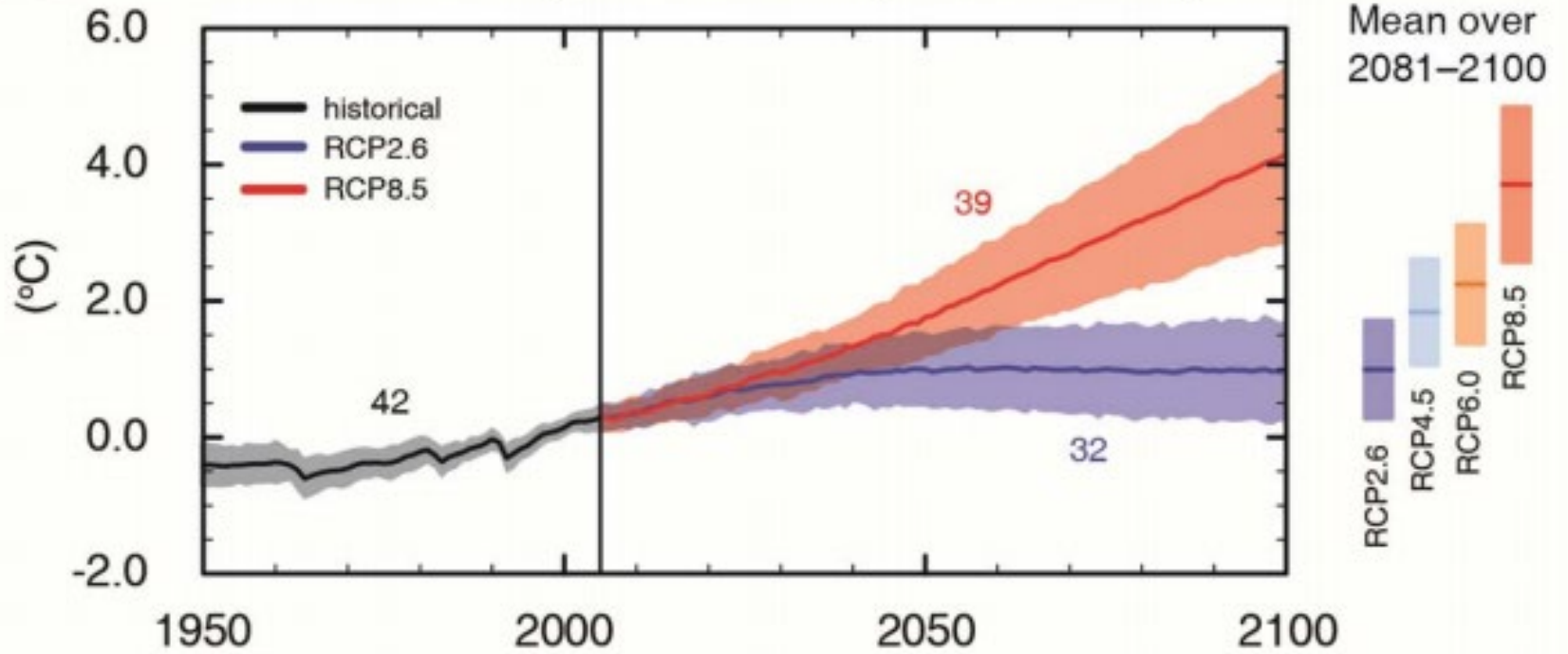
# Known Unknowns

Two main sources of uncertainty in climate projections:

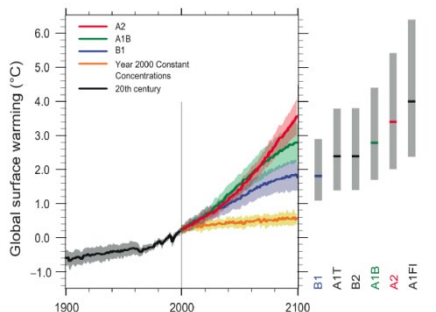
1. Climate models
2. Future greenhouse gas emissions



# Global average surface temperature change

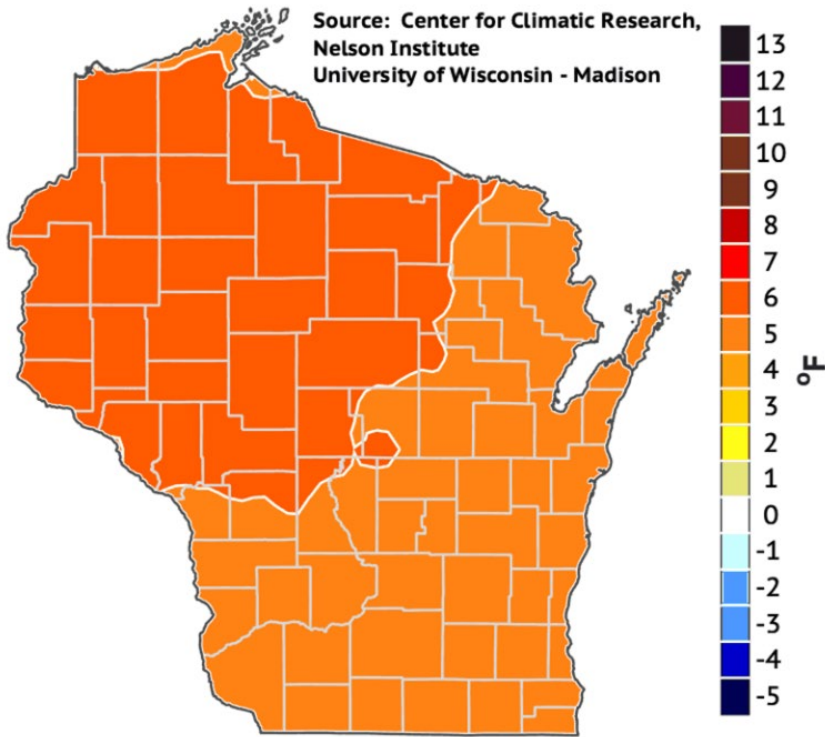


Multi-model Averages and Assessed Ranges for Surface Warming



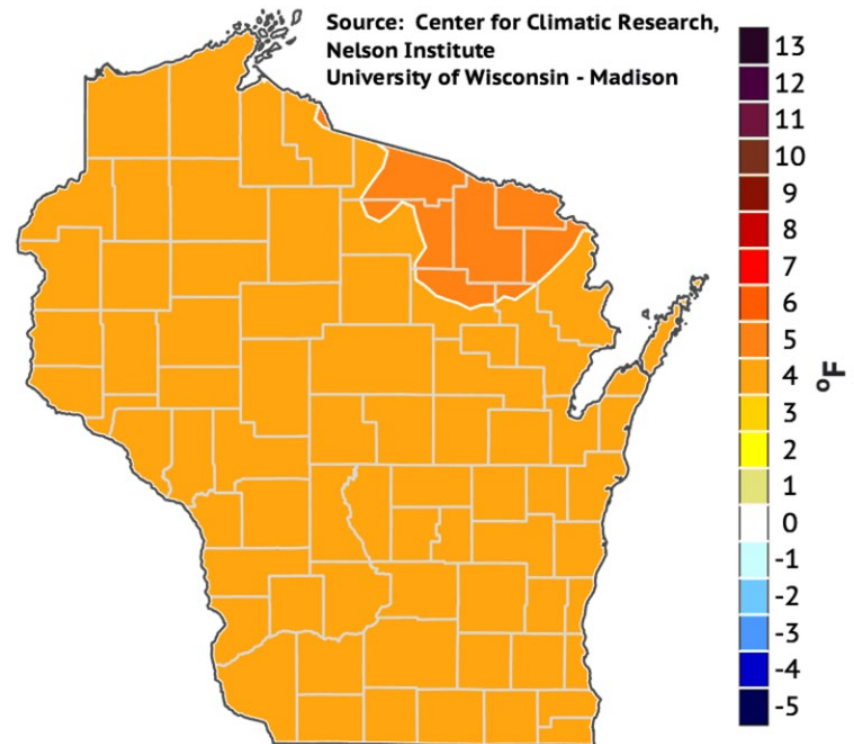
# Temperature Change - Projected

**Change in DJF TMEAN, RCP45:  
2041-2060 minus 1981-2010**



**Winter**

**Change in JJA TMEAN, RCP45:  
2041-2060 minus 1981-2010**

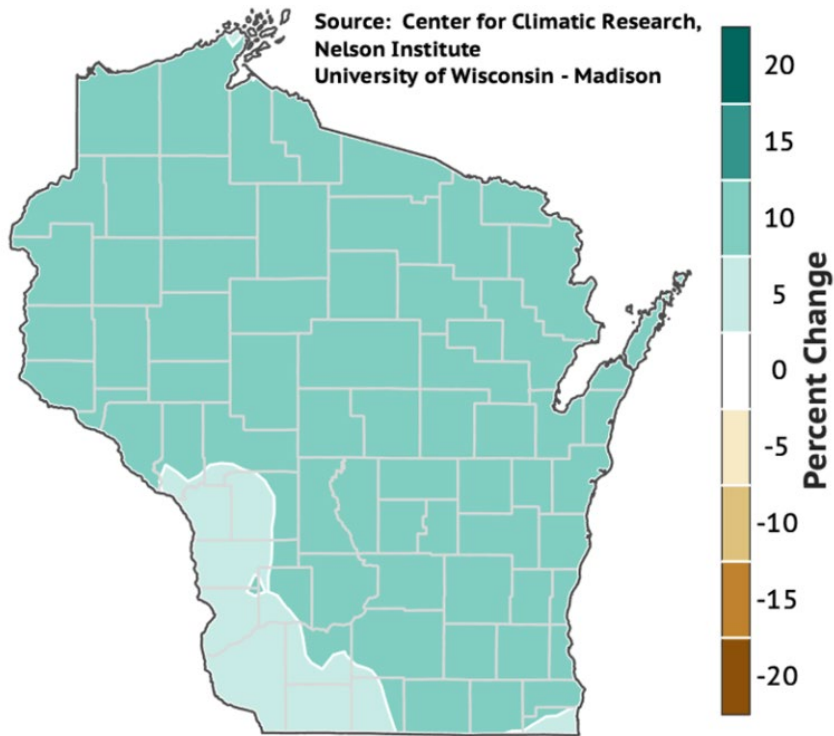


**Summer**



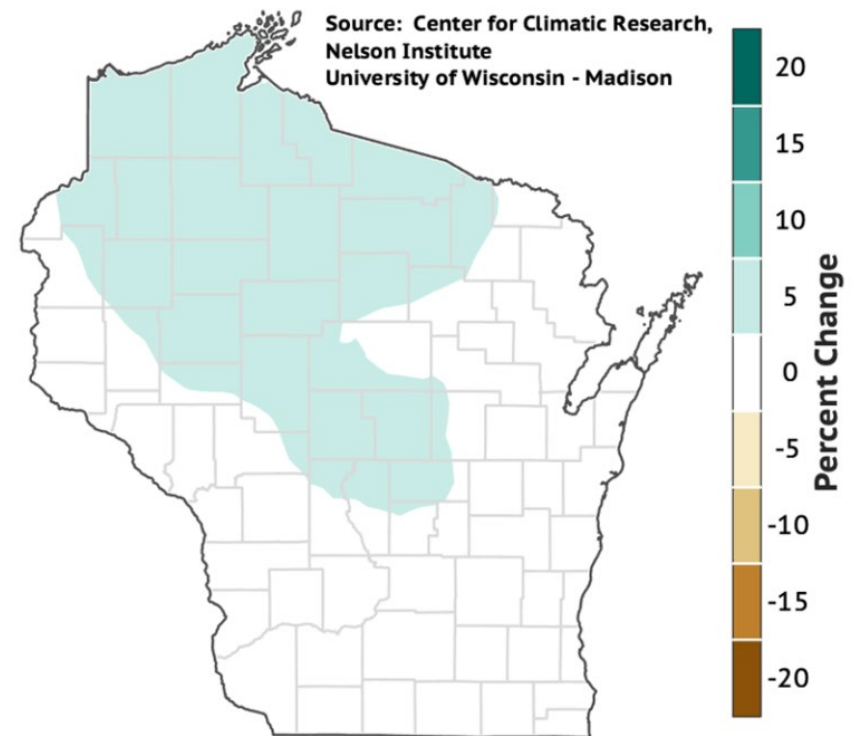
# Precipitation Change - Projected

**Change in DJF PRCP (%), RCP45:  
2041-2060 minus 1981-2010**



**Winter**

**Change in JJA PRCP (%), RCP45:  
2041-2060 minus 1981-2010**



**Summer**

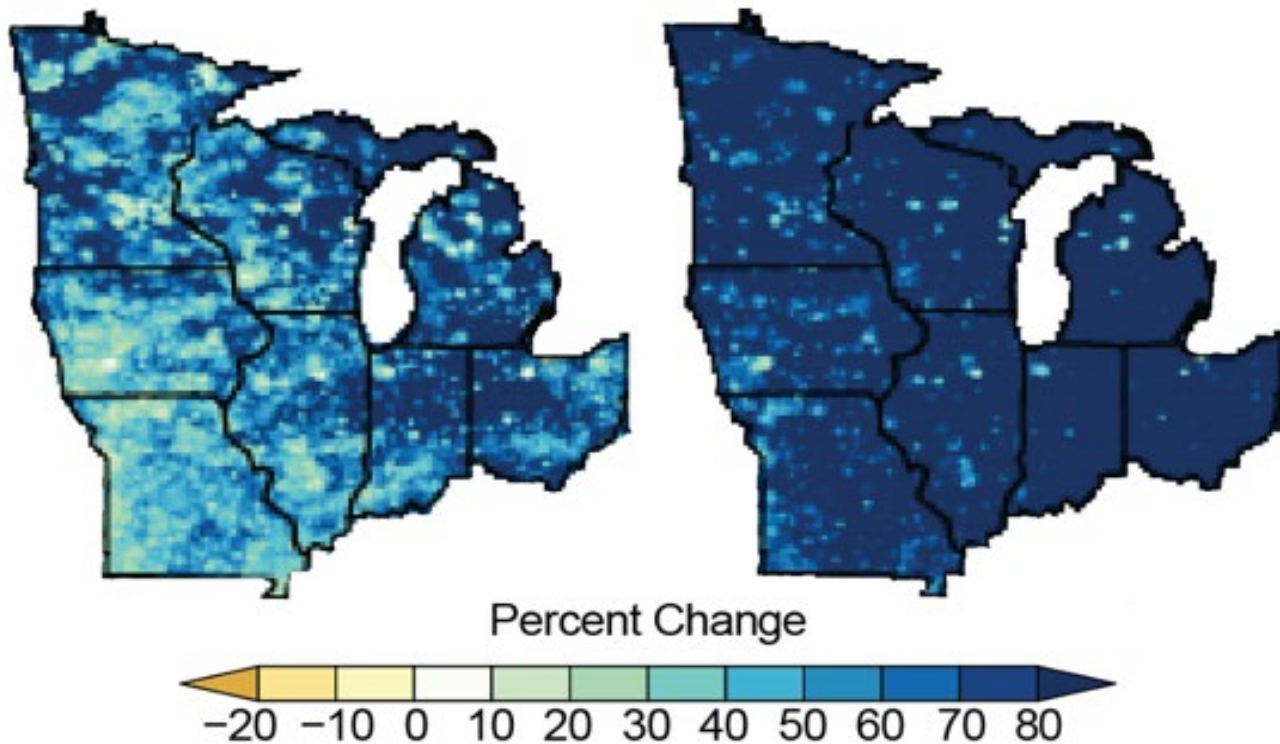


# Extreme Rain Events

Change in Annual Number of Extreme Precipitation Days,  
Late 21st Century

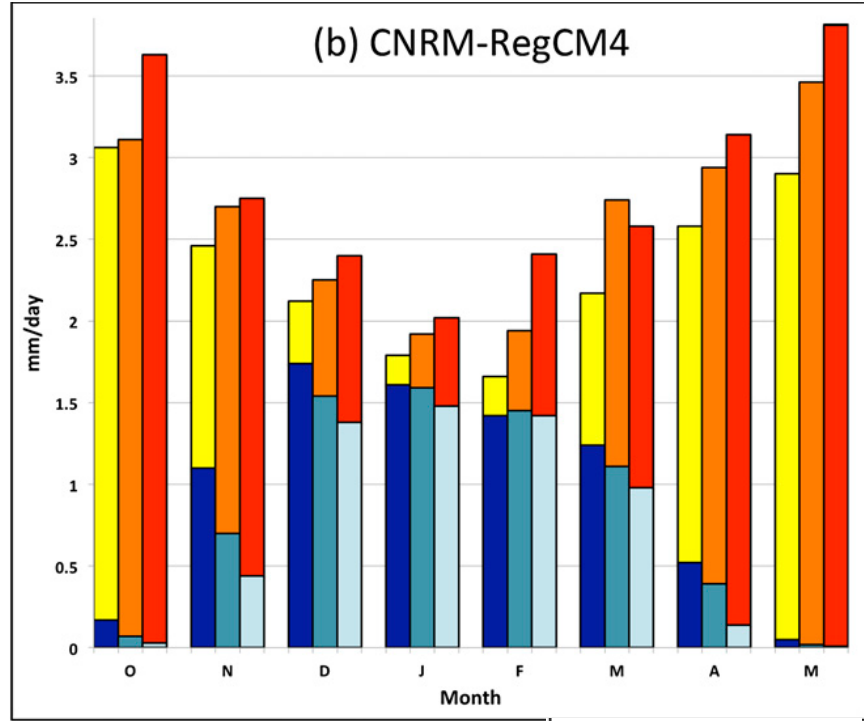
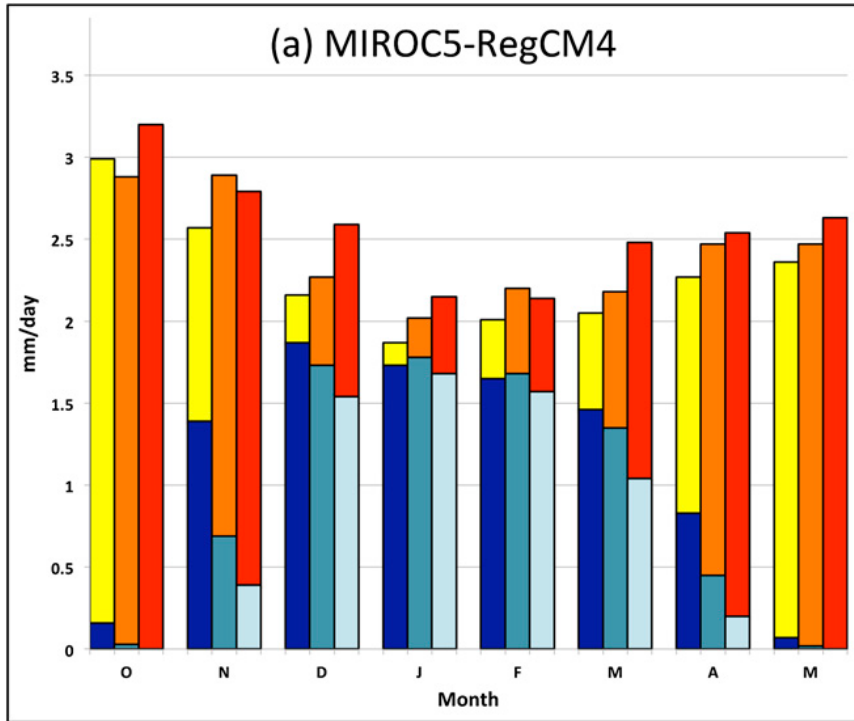
Lower Emissions (RCP4.5)

Higher Emissions (RCP8.5)

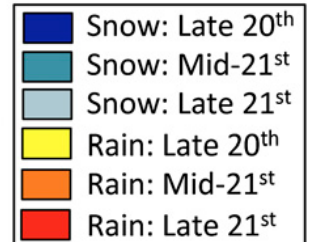


# Winter Rain

- Dynamically downscaled RCP 8.5



\*Transition to rain, especially for Nov, Mar, April

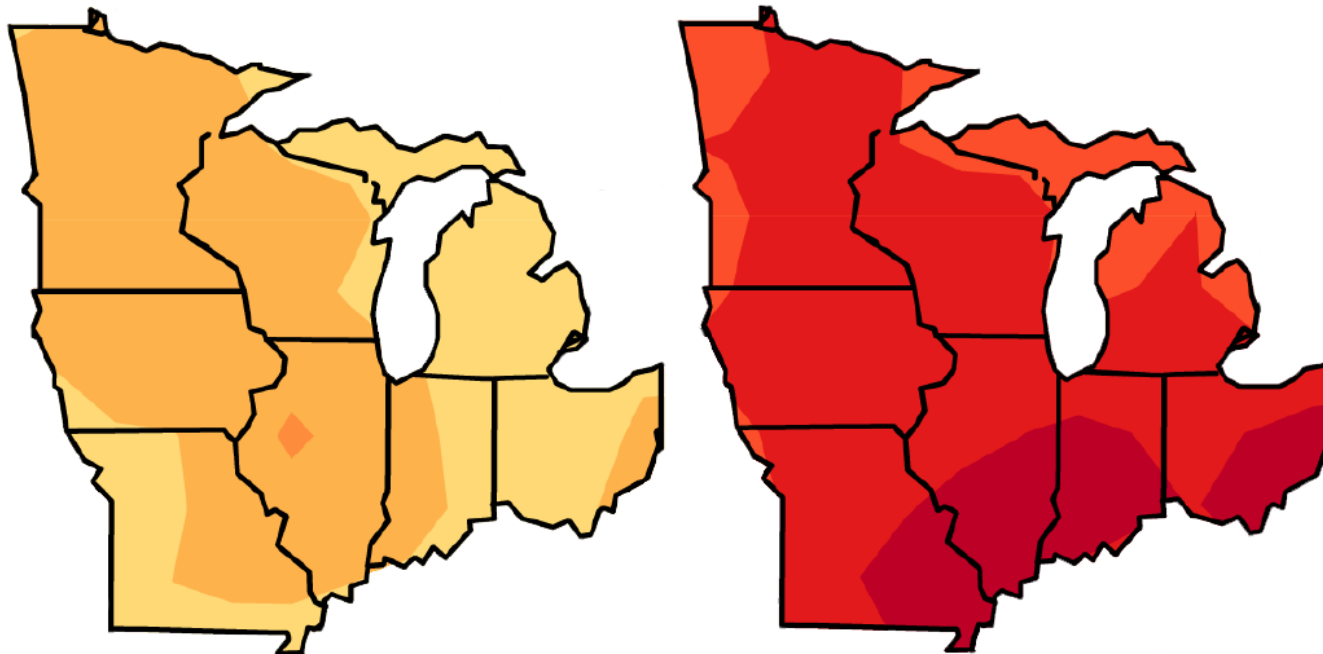


# More Drought Stress

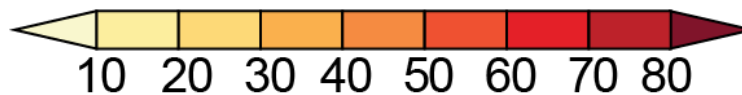
Change in Annual Maximum 5-day  
Vapor Pressure Deficit, Late 21st Century

Lower Emissions (RCP4.5)

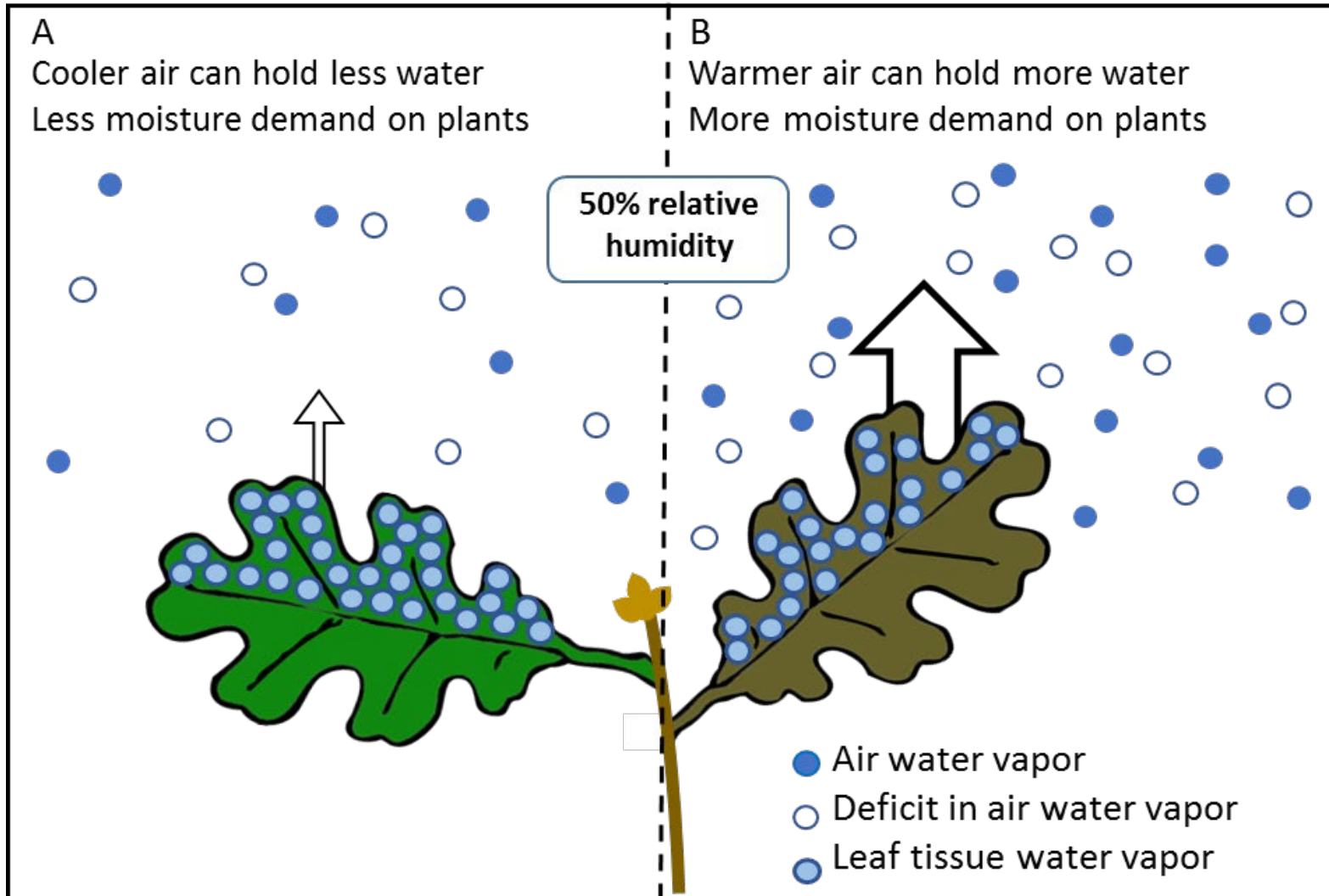
Higher Emissions (RCP8.5)



Percent Change

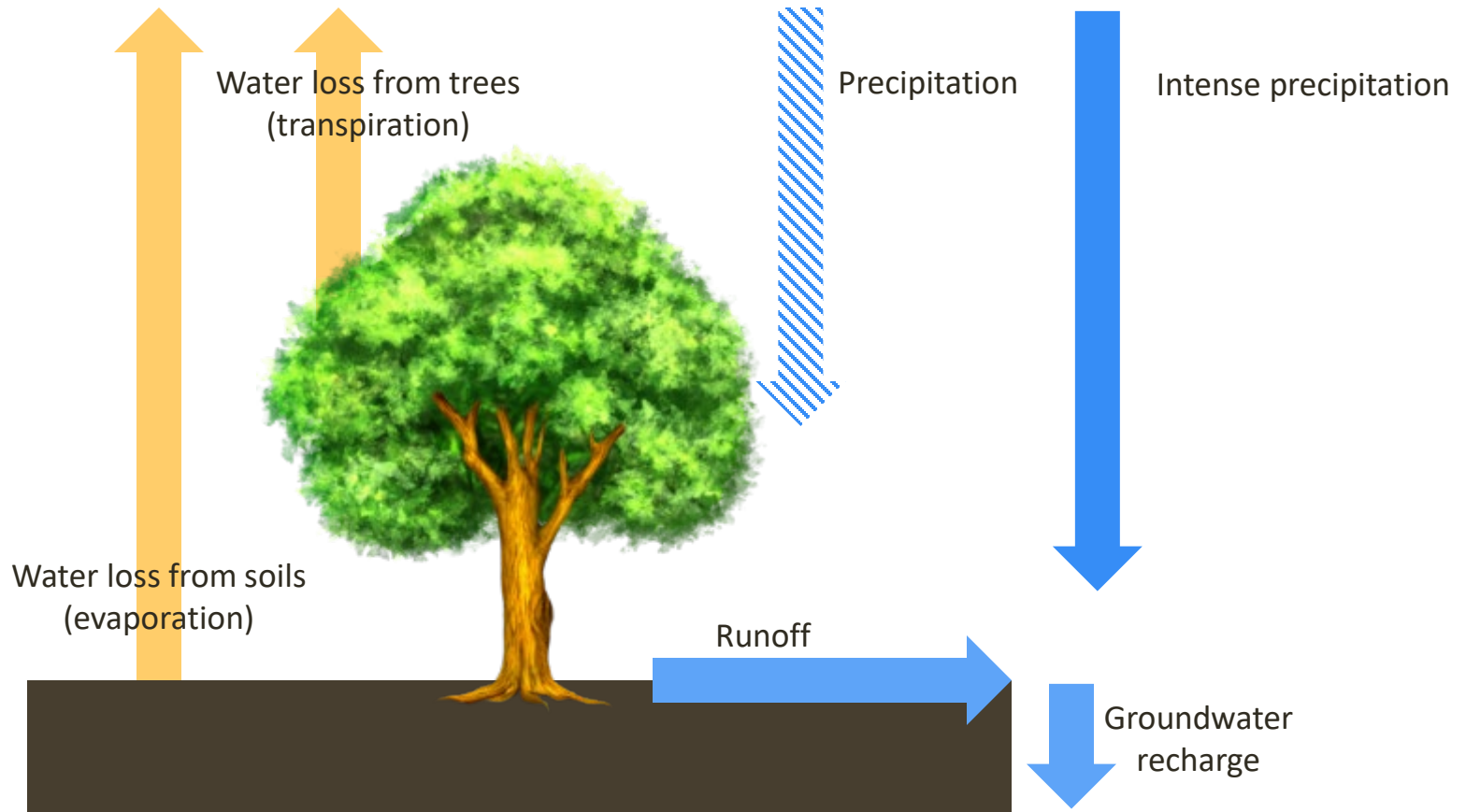


# More Drought Stress



# More Drought Stress

Greater uncertainty about future precipitation,  
but great risk of summer moisture stress



# Species Range Shifts

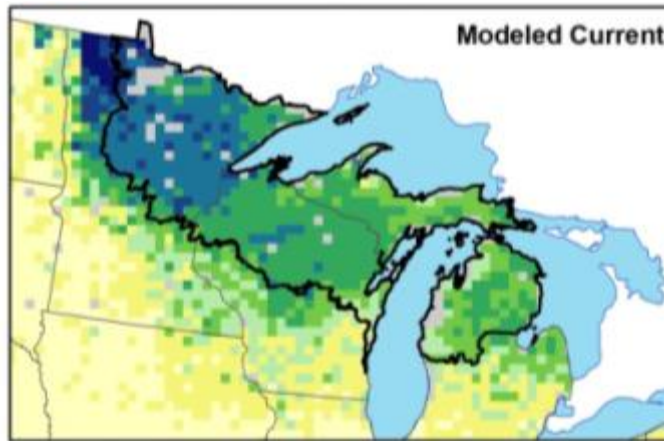
## Quaking Aspen

Importance  
Value

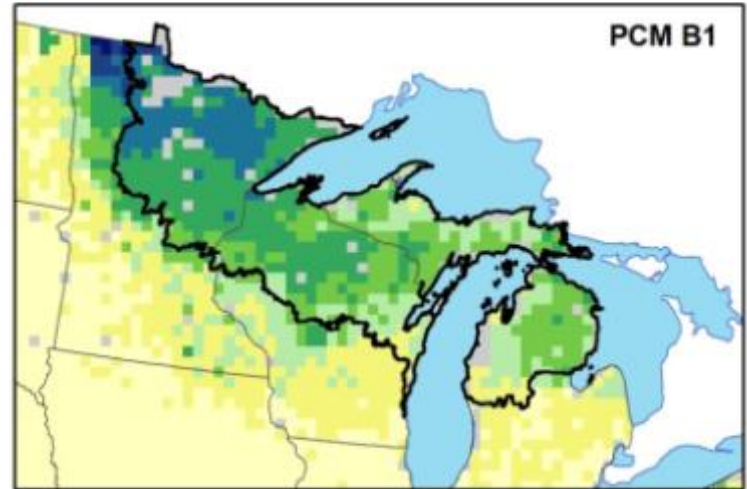
Low

High

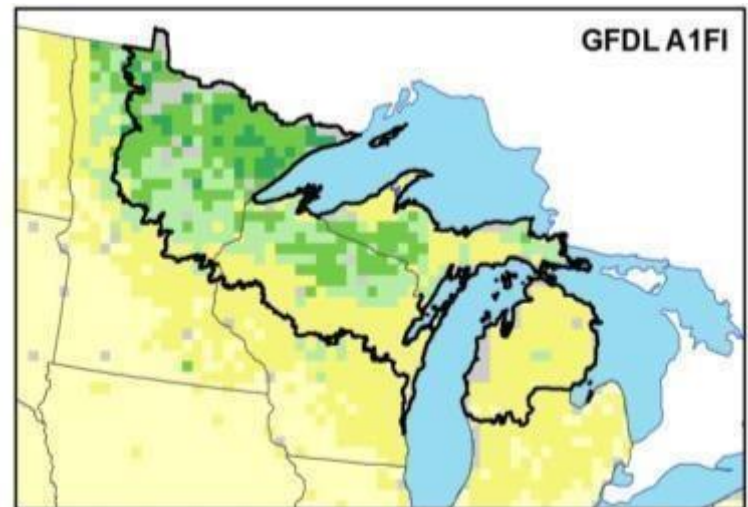
Current



2070-2100 Low



2070-2100 High



# Species Range Shifts

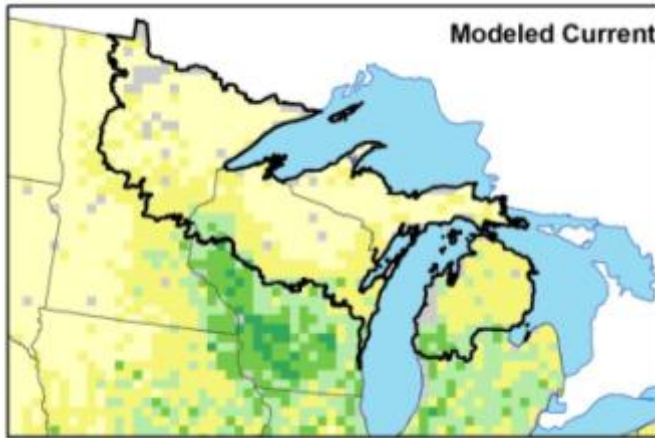
## White Oak

Importance  
Value

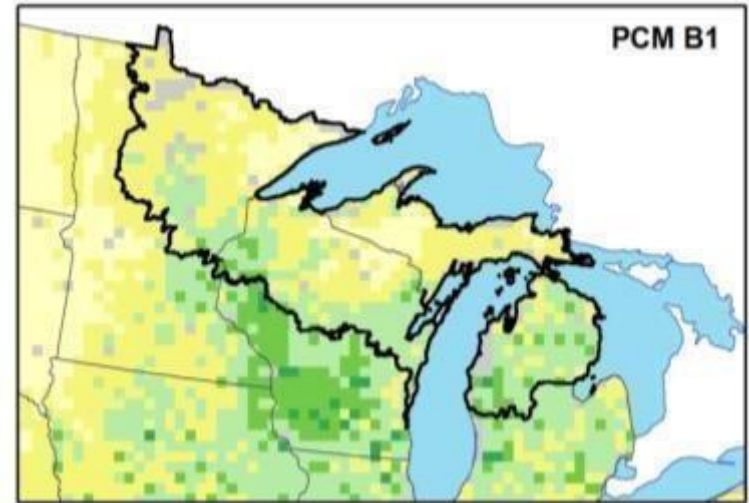
Low

High

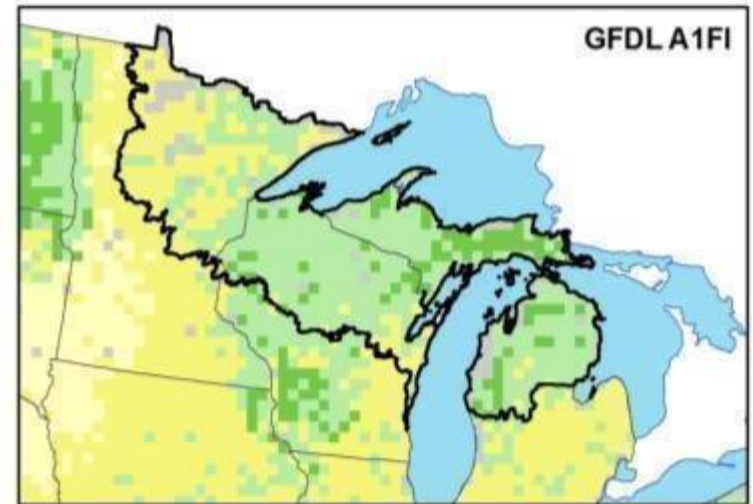
Current



2070-2100 Low




2070-2100 High



# Species Range Shifts


Handouts for many different regions:

- Northern MN
- Northern WI & western UP
- Eastern UP & northern LP
- Driftless Area
- Southern WI
- Southern MI



## CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

### NORTHERN WISCONSIN AND WESTERN UPPER MICHIGAN



Northern forests will be affected by climate change during this century. A team of forest managers and researchers created a report that describes the vulnerability of forests in northern Wisconsin and western Upper Michigan (Janowiak et al. 2014). This report includes information on the current landscape, observed climate trends, and a range of projected future climates. It also describes many potential climate change impacts to forests and summarizes key vulnerabilities for major forest types. This handout is summarized from the full report.


**TREE SPECIES INFORMATION:**  
This report uses two climate scenarios to "bracket" a range of possible futures. These future climate projections were used with two forest impact models (Tree Atlas and LANDIS) to provide information about how individual tree species may respond to a changing climate. More information on the climate and forest impact models can be found in the full report. This page shows the most common tree species in this local area, organized into general categories of future expectations. Results for all species can be compared side-by-side on page 2.

SPECIES	ADDITIONAL CONSIDERATIONS
<b>LIKELY TO DECREASE</b>	
Balsam fir	Requires cold climate and susceptible to drought, fire, and insects
Black ash	Emerald ash borer causes mortality
Black spruce	Requires cold climate, susceptible to insect pests and drought
Northern white-cedar	Requires cold climate and susceptible to fire and herbivory
Paper birch	Early-successional colonizer, but susceptible to insects and drought
Quaking aspen	Early-successional colonizer, but susceptible to heat and drought
White spruce	Requires cold climate, susceptible to insect pests
Yellow birch	Good disperser, but susceptible to fire, insects, and disease
<b>MAY DECREASE</b>	
Balsam poplar	Early-successional colonizer but susceptible to drought
Eastern white pine	Good disperser, but susceptible to drought and insects
Jack pine	Tolerates drought and fire, but susceptible to insect pests
Red pine	Susceptible to insect pests and diseases, and limited dispersal.
Sugar maple	Grows across a variety of sites and tolerates shade
Tamarack	Requires cold climate and susceptible to drought, fire, and insects


Remember that models are just tools, and they're not perfect. Models don't account for some factors that could be modified by climate change, like droughts, wildfire activity, and invasive species. If a species is rare or confined to a small area, Tree Atlas results may also be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions.

Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change. The model results presented here were combined with information from published reports and local management expertise to draw conclusions about potential risk and change in the region's forests.

SPECIES	ADDITIONAL CONSIDERATIONS
<b>MIXED MODEL RESULTS</b>	
Bigtooth aspen	Early-successional colonizer, but susceptible to drought
Eastern hemlock	Hemlock woolly adelgid causes mortality
Green ash	Emerald ash borer causes mortality
Red maple	Competitive colonizer tolerant of disturbance and diverse sites
<b>NO CHANGE</b>	
Northern red oak	Susceptible to some insect pests and oak wilt
<b>MAY INCREASE</b>	
American basswood	Tolerates shade but susceptible to fire
American elm	Affected by Dutch elm disease, grows across a variety of sites
American hornbeam	Shade-tolerant, but susceptible to fire and drought
Black cherry	Susceptible to insects and fire, tolerates some drought
Bur oak	Tolerates drought and fire
Ironwood	Grows across a variety of sites and tolerates shade
Northern pin oak	Tolerates drought and fire
White ash	Emerald ash borer causes mortality
White oak	Fire-adapted and grows on a variety of sites



[www.forestadaptation.org](http://www.forestadaptation.org)



Get this handout on line at: [www.forestadaptation.org/Northwoods\\_treehandouts](http://www.forestadaptation.org/Northwoods_treehandouts)

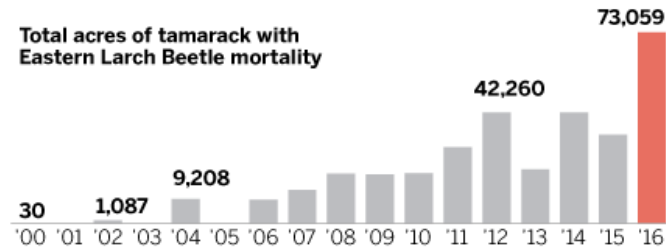
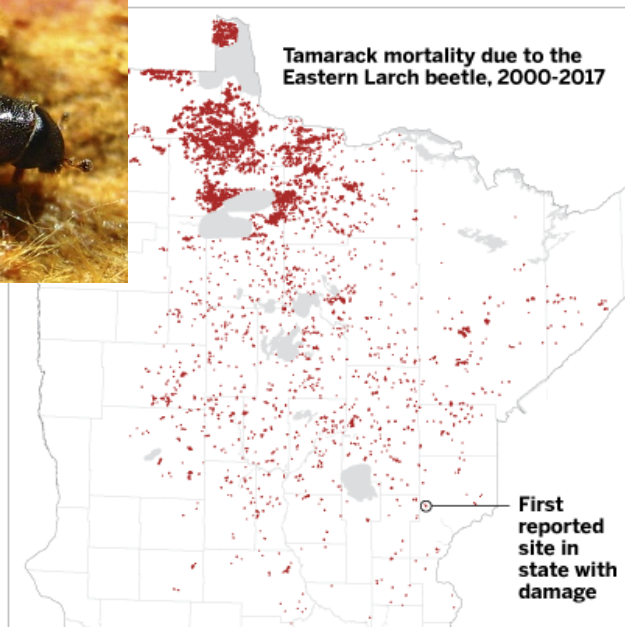


# Pests and Diseases

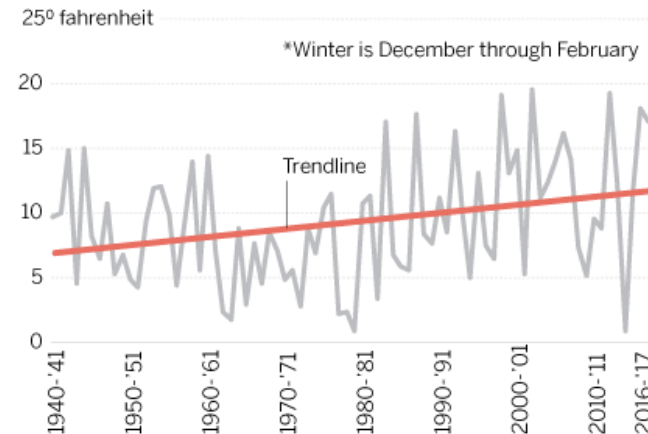
Climate change can trigger more damage from pests.

## INFESTATION DRIVEN BY CLIMATE CHANGE

Eastern larch beetles, a tiny bug native to Minnesota, have killed or damaged more than a quarter million acres of tamarack trees in the state. Scientists who studied the bug say the population is growing exponentially because longer, warmer summers now allow them to produce two generations a year, and warmer winters mean more of them survive to reproduce the next year.



**Average winter\* low temperature and trendline at MSP airport**  
Average temperatures in Minnesota have been on the rise for decades. That's especially true for winters in the northern part of the state, which are warming ten times faster than summers. The extreme lows of 35 degrees Fahrenheit or less that used to happen eight or ten times a year are now a rarity, likely contributing the explosion of Eastern Larch Beetles.



Sources: USDA Forest Service, Midwestern Regional Climate Center, Climate Central, U.S. Geological Survey

RAY GRUMNEY • Star Tribune

Ray Grumney, Star Tribune. Photo: Fraser McKee

# Pests and Diseases

Expectations for spruce budworm are mixed:

- Warmer temps may actually increase synchrony between spruce budworm, balsam fir, and black spruce, causing more damage (*defoliation and budburst shift together*)
- Acres of defoliation and years of defoliation in southern Ontario projected to decline over time (*insect and host both move northward*)



# Extreme Weather Events

Extreme events are rare and hard to model.

- Uncertainty is very high
- High wind events may increase in northern latitudes (above 40-50°)
- Average wind speeds may decrease slightly across the central US
- Regeneration may not follow the usual pattern



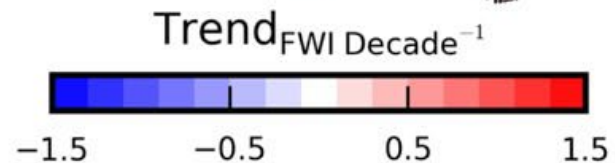
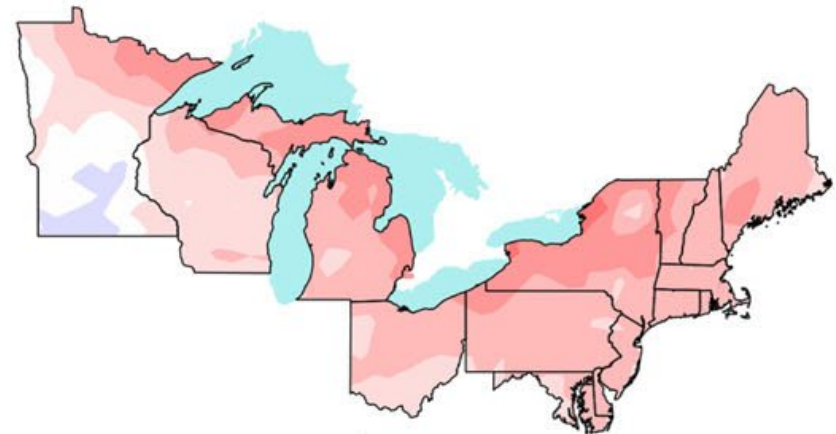
# Wildfire Risk

## Fire may increase, because:

- Warmer/drier summers
- Increased mortality from stress, pests, events
- More frequent weather conditions that promote large fires



1989-2100



FWI = Fire Weather Index values



# Wildfire Risk

## Fire may increase, because:

- Warmer/drier summers
- Increased mortality from stress, pests, events
- More frequent weather conditions that promote large fires

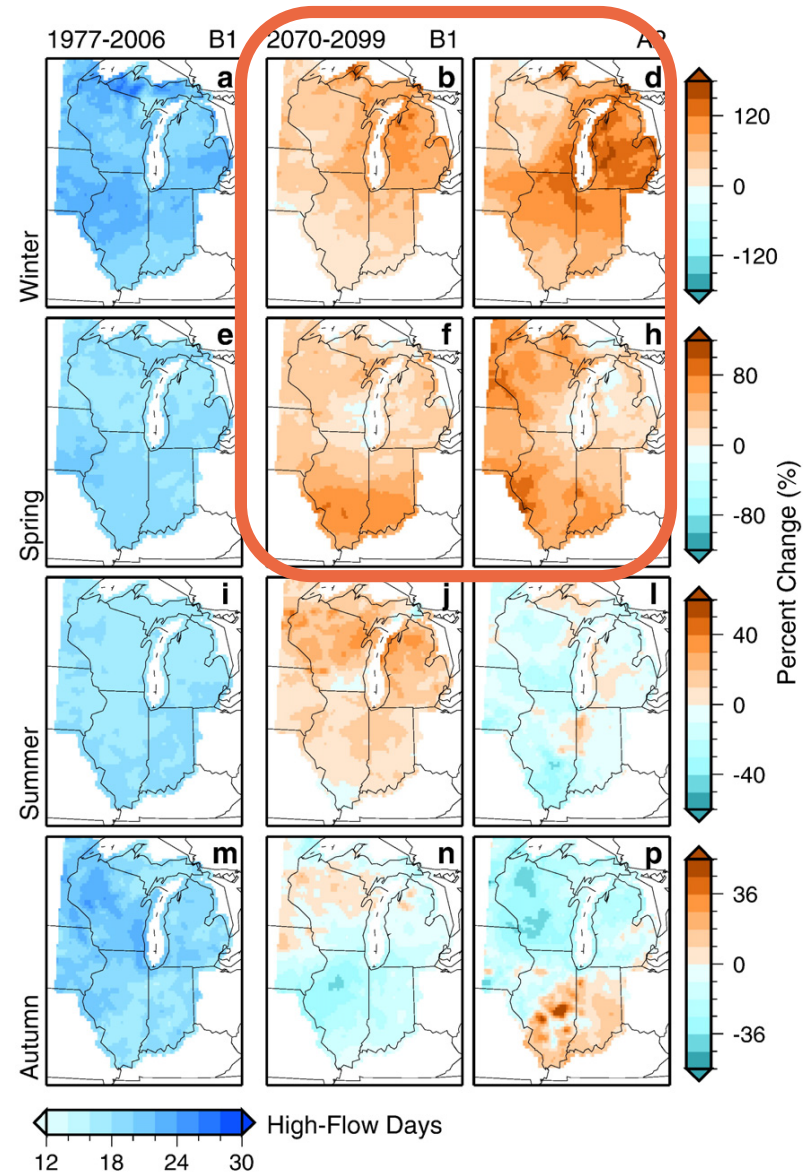
## ...or maybe not, because:

- Fire suppression will continue
- Spring/early summer moisture
- Current regeneration of more mesic species
- Spatial patterns of land use and fragmentation



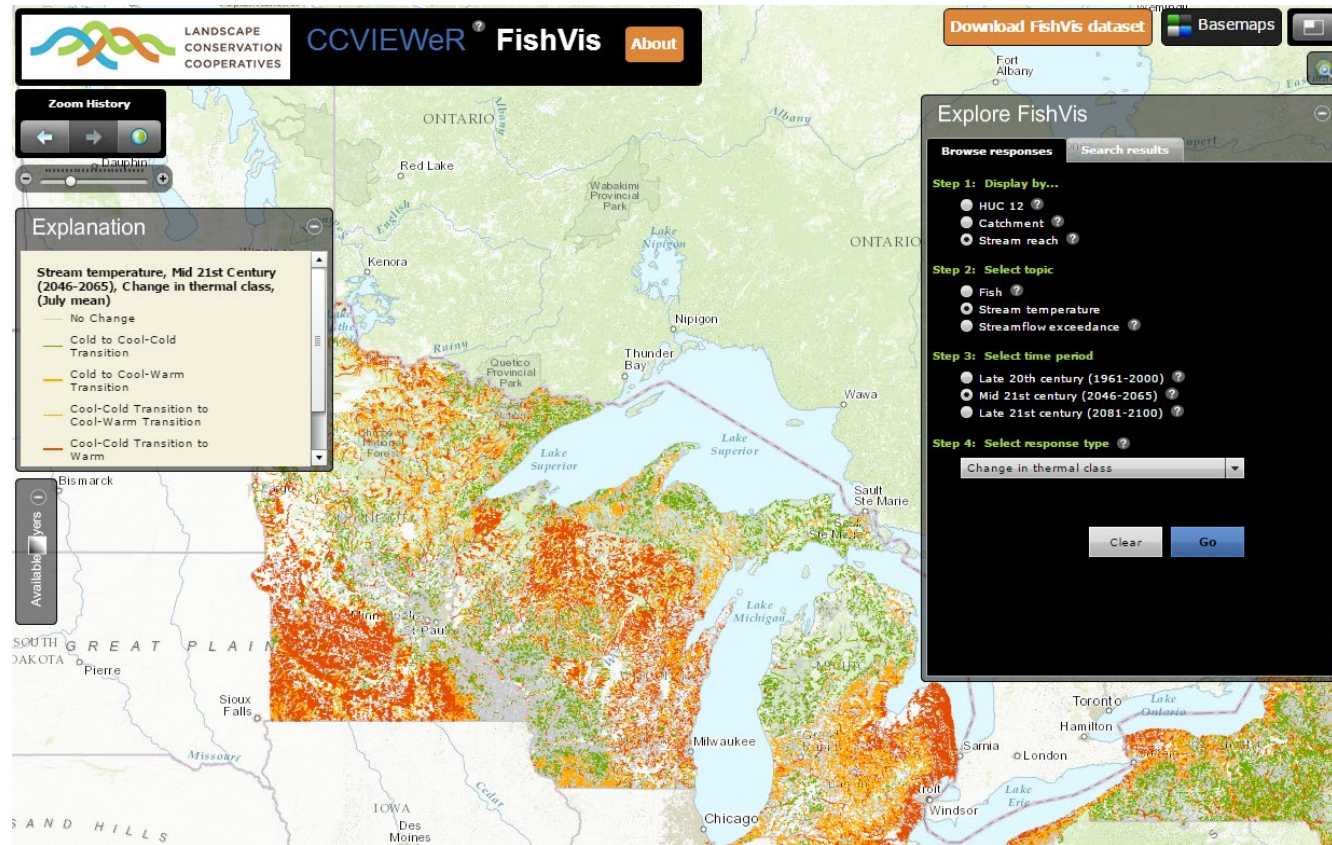
# Streamflow Changes

- High-flow days become much more common in winter and spring
- Low-flow days become much more common in summer and fall



# Warmer Stream Temps

- Stream temp. class changes
- Streamflow exceedance



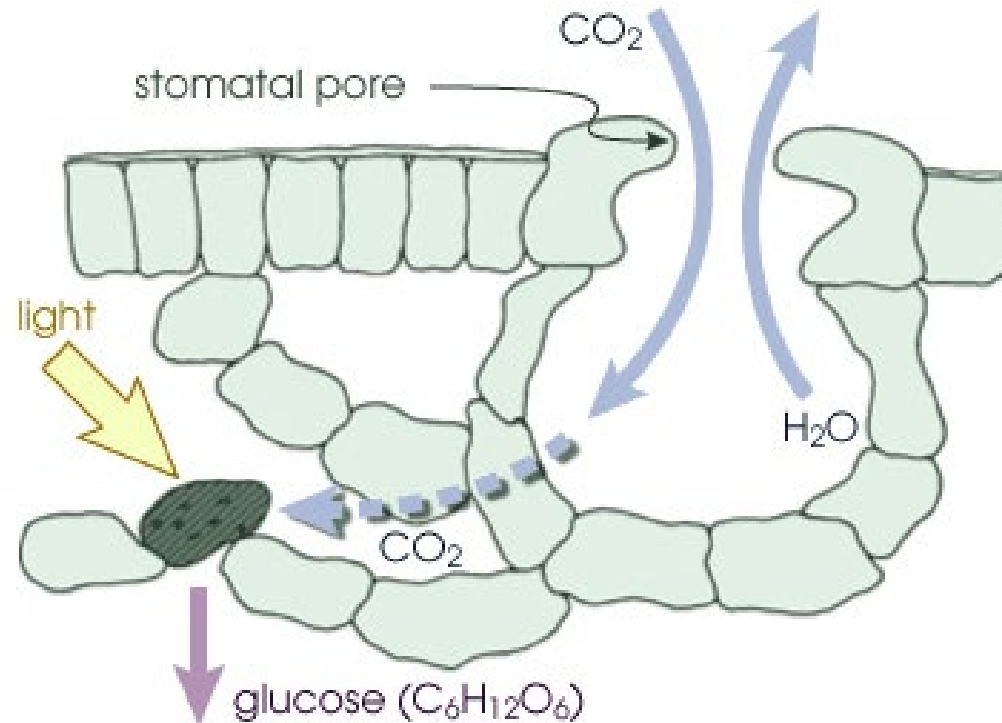
# CO<sub>2</sub> Fertilization

## Benefits:

- Increased growth
- Water-use efficiency

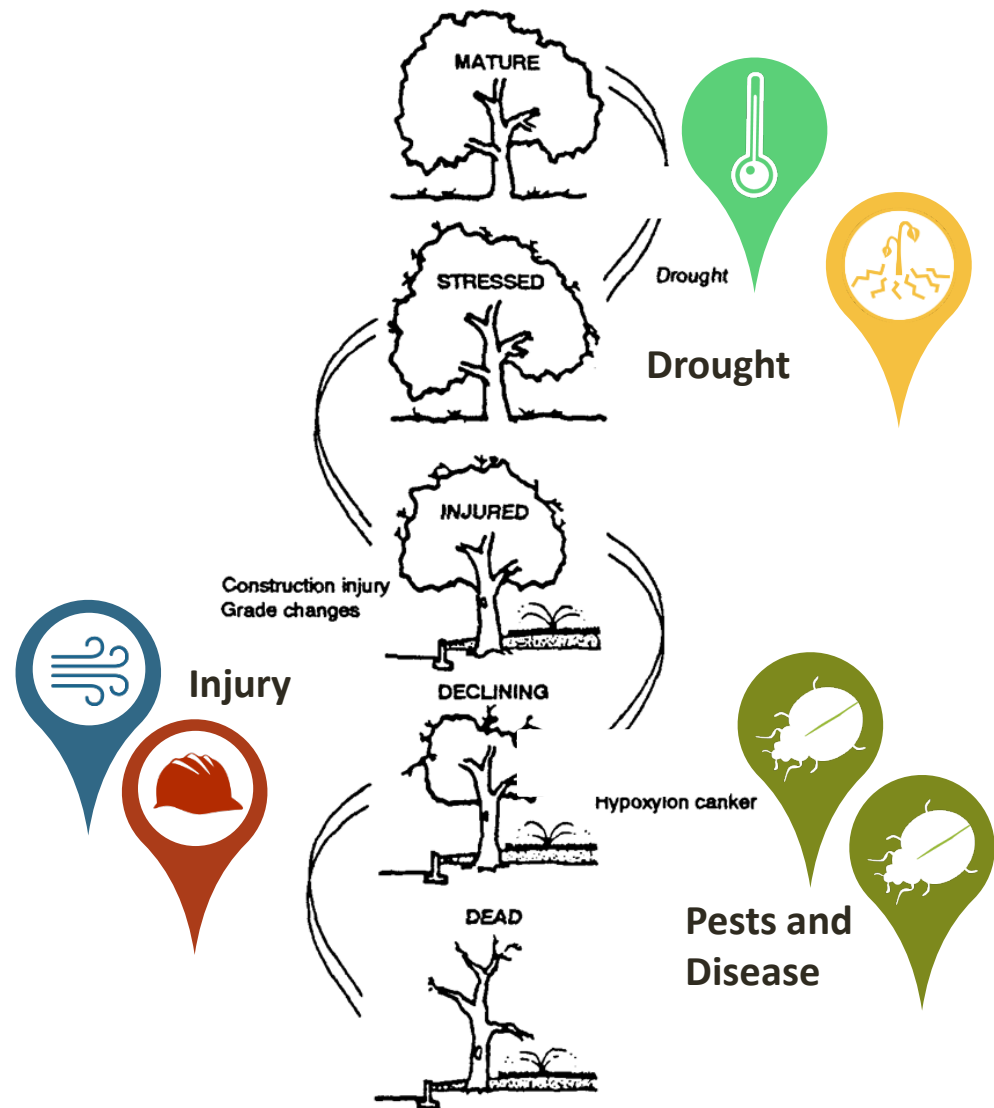
## Limits:

- Other nutrients or water
- Stressors or disturbance



# A “Threat Multiplier”

- Interactions can trigger big changes
  - Stress
  - Disturbance
  - Invasive species
  - Insect pests
  - Forest diseases



# Forest Type Vulnerability



Acid peatland  
Forested rich peatland  
Wet forest  
Managed aspen  
Managed red pine  
Fire-dependent forest  
Mesic hardwood forest  
Floodplain forest

Lowland conifer  
Upland spruce-fir  
Aspen-birch  
Lowland/riparian  
hardwoods  
Red pine  
Northern hardwoods  
Jack pine  
Oak  
White pine

Upland spruce-fir  
Lowland conifer  
Red pine/ white pine  
Jack pine  
Aspen-birch  
Northern hardwoods  
Lowland/riparian  
hardwoods  
Oak associations  
Barrens





# Be like Wayne

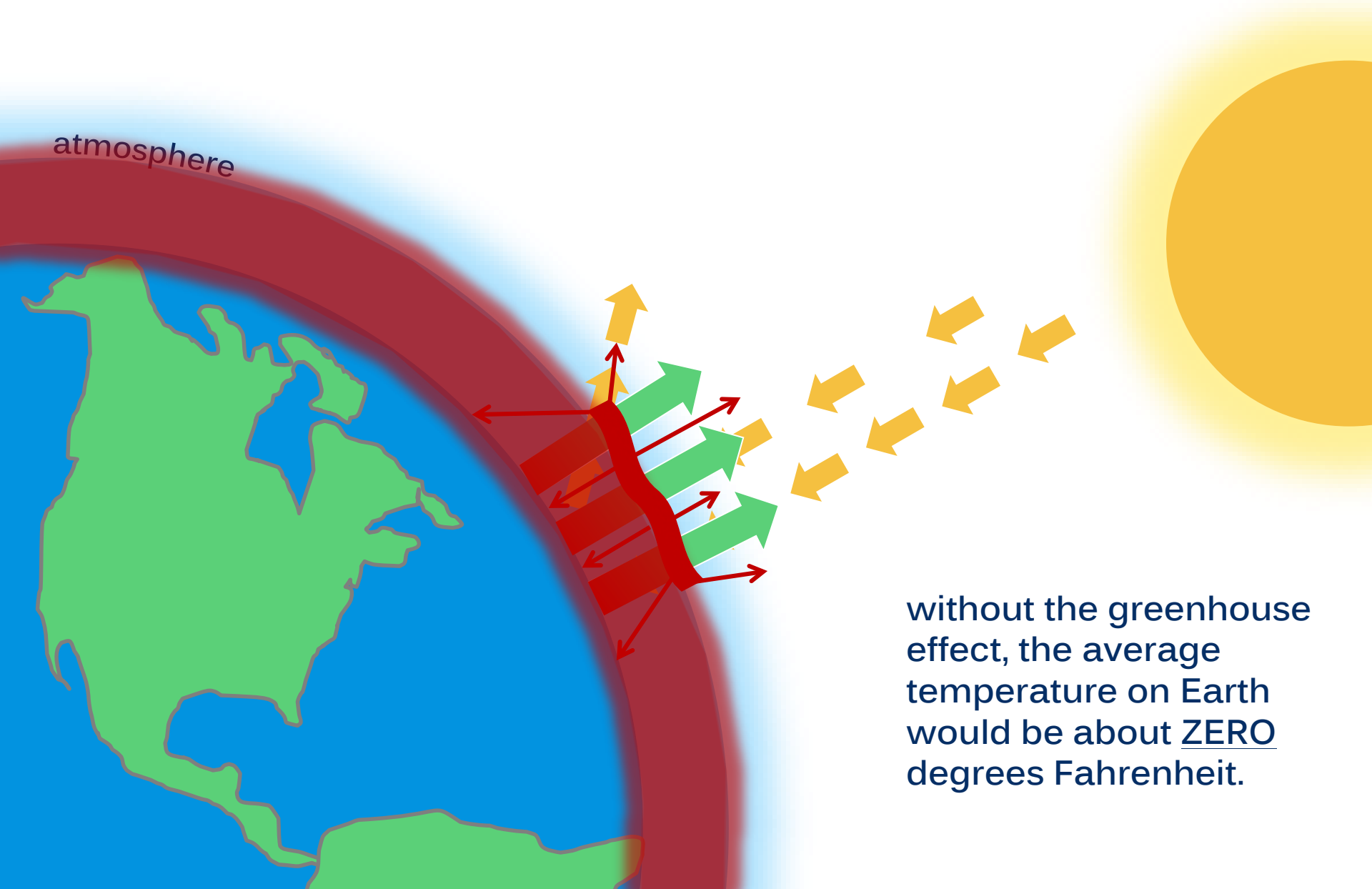


"I skate to where the puck is going to be, not where it has been."  
-- Wayne Gretzky

# Next Steps

- Stephen will share presentation today
- Stephen will join Oct meeting and discuss pre-work
- Consider this information as you consider the Purpose and Need, actions on adjacent stands, and specific needs for your resource area.
- **Get in touch with questions!**

# Greenhouse effect



without the greenhouse effect, the average temperature on Earth would be about ZERO degrees Fahrenheit.

# Not a New Idea

We've know about the greenhouse effect for almost 200 years!

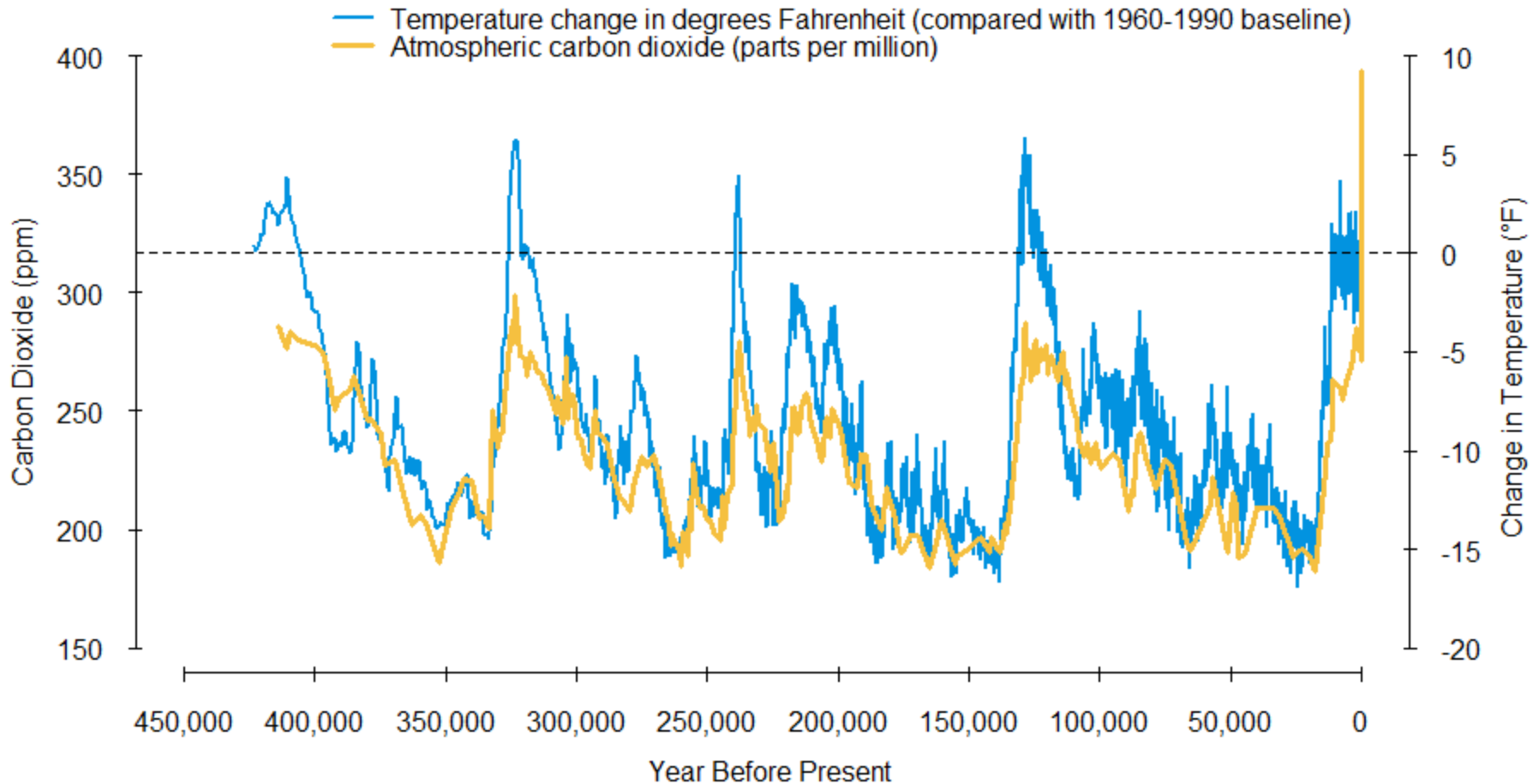
- Fourier, 1824
- Pouillet, 1827
- Arrhenius, 1896



# Change Happens

- Climate change has happened before
- Climate change is a natural process (until now)

**Temperature and Carbon Dioxide over the Past 400,000 Years**



# It's From Fossil Fuels

- Carbon from modern times has C-14
- Carbon from fossil fuels does not (too old!)

