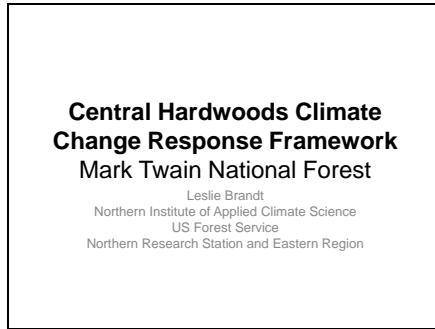
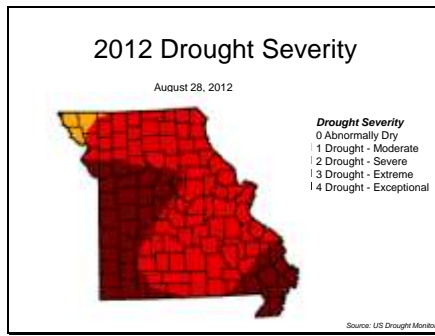


Slide 1



Slide 2



This year's drought was the first "exceptional" drought Missouri has experienced in more than 30 years. This drought has had tremendous impacts on the livelihoods and quality of life for the people of Missouri.

Slide 3



The corn crop has withered under hot, dry conditions, leading to total losses in some areas.

Slide 4



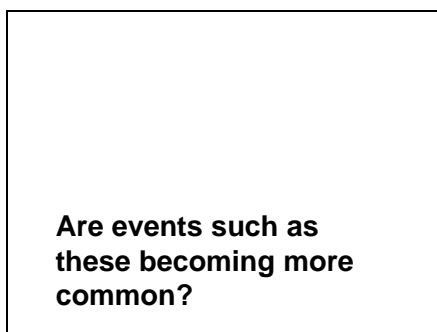
The May 22, 2011 Tornado in Joplin, MO was part of a larger late-May tornado outbreak sequence and reached a maximum width in excess of 1 mile (1.6 km) during its path through the southern part of the city. It was the deadliest tornado in US history since 1947.

Slide 5



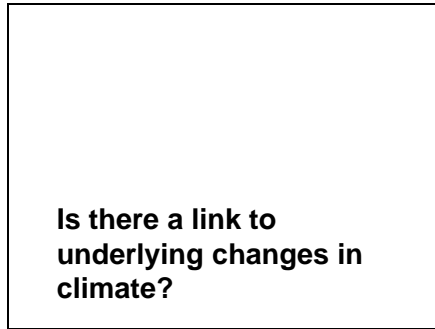
In spring 2011, major storms, combined with a heavy spring snowmelt, led to record-breaking flooding along the Mississippi and Missouri Rivers. To save the town of Cairo, Illinois and the rest of the levee system along the Mississippi River, the US Army Corps of Engineers blasted a two-mile hole in a levee flooding 130,000 acres (530 km²) of farmland and displacing 200 residents in Mississippi County, Missouri.

Slide 6



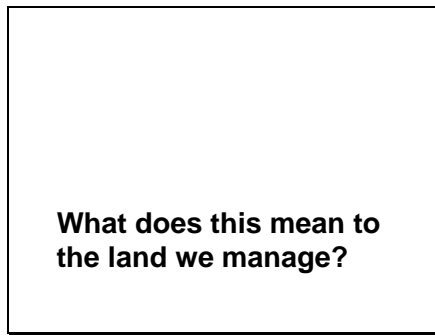
This may lead you to ask...

Slide 7



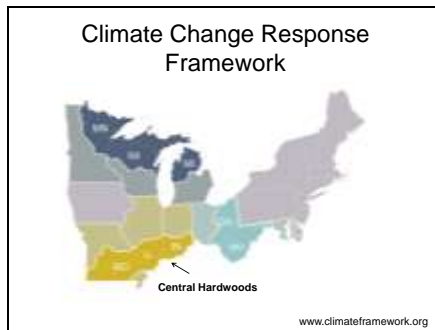
This may lead you to ask...

Slide 8



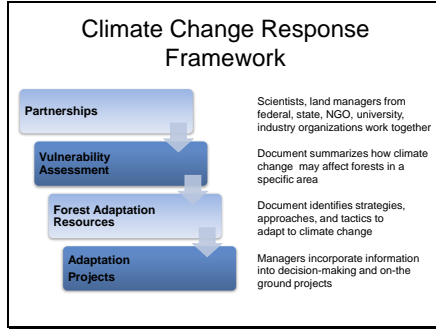
This may lead you to ask...

Slide 9



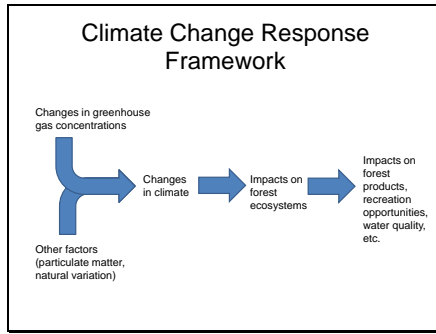
To answer questions such as these, scientists and land managers at the Forest Service and their partners have come together to develop the "Climate Change Response Framework". Three ecoregional Framework projects are currently underway. The Mark Twain and its partners in the Missouri Ozarks are part of the Central Hardwoods Climate Change Response Framework project.

Slide 10



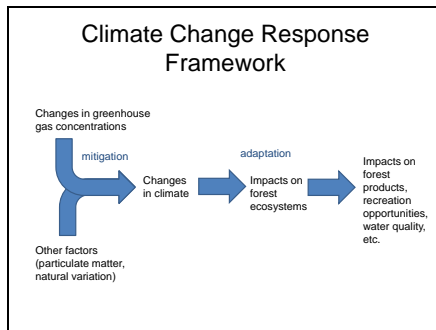
The Climate Change Response Framework has four major components: partnerships, vulnerability assessments, forest adaptation resources, and adaptation projects.

Slide 11



The climate change response framework seeks to understand how natural and human-induced changes in climate may impact forest ecosystems and the benefits they provide to aid in decision-making.

Slide 12

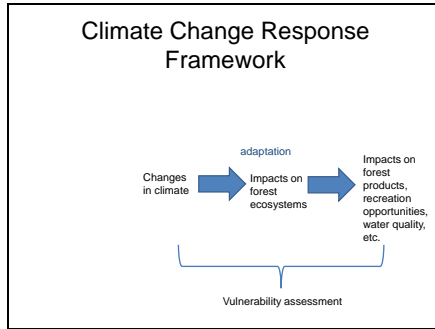


There are two important aspects of decision-making related to climate change:

Mitigation seeks to reduce human-induced change in greenhouse gas emissions.

Adaptation seeks to reduce the vulnerability of natural and human systems to actual or expected climate change effects.

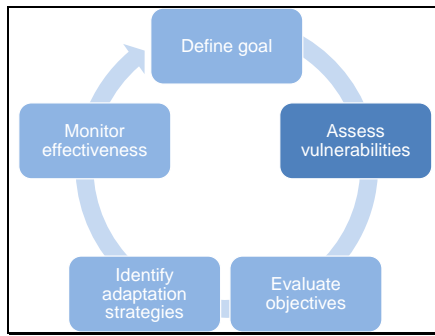
Slide 13



The climate change response framework focuses on adaptation.

The vulnerability assessment determines what the potential impacts may be assuming no adaptation actions are taken.

Slide 14



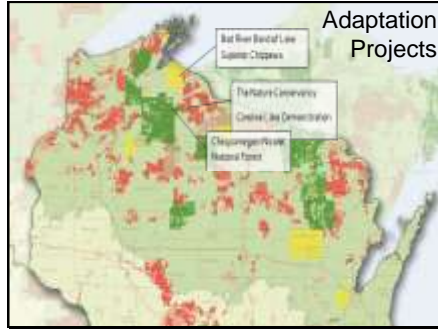
This vulnerability information can then be incorporated into planning using the workbook developed as part of the forest adaptation resources document.

Slide 15



The ultimate goal is to use this information in adaptation projects. In these projects, we work with managers to use the workbook approach on a real-world project. The workbook helps managers identify areas where management may need to be adjusted to account for current or projected climate change, and helps us identify things we may already be doing to confront these changes.

Slide 16



In northern Wisconsin, where a vulnerability assessment has already been completed, 3 adaptation projects are currently underway focused on the bad river watershed.

Slide 17

Caroline Lakes Upland Hardwoods

CURRENT MANAGEMENT

- Objective: maintain species composition/ diversity and increase structural diversity
- Practice: single-tree or group selection

POSSIBLE ADAPTATION ACTIONS

- Increase gap sizes to enhance species diversity and age class diversity
- ★ Large group selection or shelterwood harvests to promote red oak in areas where natural regeneration is present
- ★ Promote white pine and other species that are expected to fare better under climate change through release of advance regeneration or underplanting
- Convert portion of one stand to an oak forest type
- Reserve high-quality pockets of hemlock to serve as refugia for that species

The complex block contains text, a list of management and adaptation actions, and two photographs. The top photograph shows a tall, thin tree in a forest, and the bottom photograph shows a dense forest floor with green vegetation.

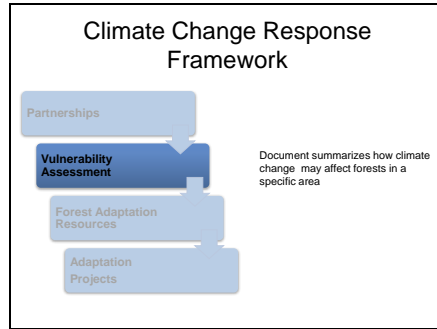
Each organization reviews its individual land management practices and objectives and walks through the workbook to identify relevant adaptation strategies and specific stand-level tactics.

For example, an upland hardwood stand was selected for a demonstration.

Its current management practices and objectives were evaluated, and then 5 adaptation actions were identified that may be helpful in the face of climate change.

Two of these have been selected for incorporation into a revision of TNC's land management plan.

Slide 18



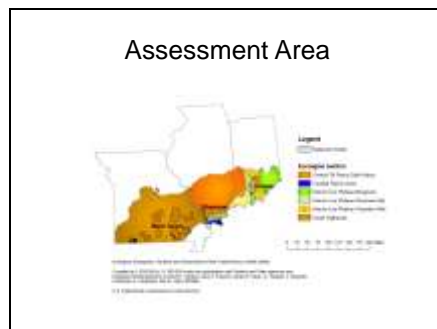
Today, I'm going to give you a sneak peak at some of the discoveries we have made in undertaking the vulnerability assessment for the central hardwoods region.

Slide 19

- ### Questions
1. How has climate changed in the Missouri Ozarks over the past century?
 2. How is climate projected to change in the Missouri Ozarks over the next century?
 3. What does this mean for the forests we manage?

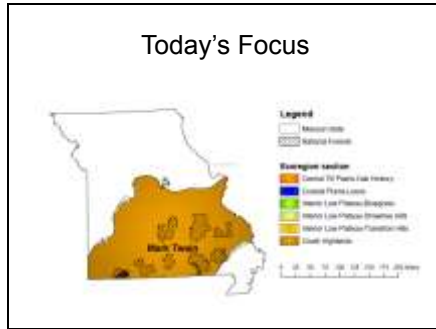
I will focus on three questions:

Slide 20



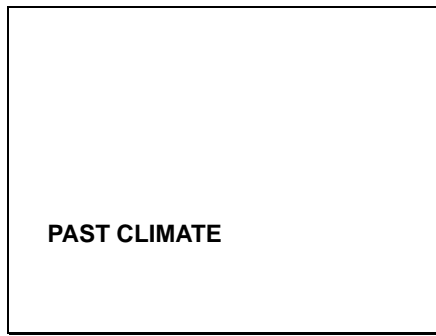
The assessment covers ecological province 223, Central Interior Broadleaf Forest, of the National Hierarchical Framework of Ecological Units, in MO, IL, and IN. This area was selected based on a combination of political and ecological boundaries.

Slide 21



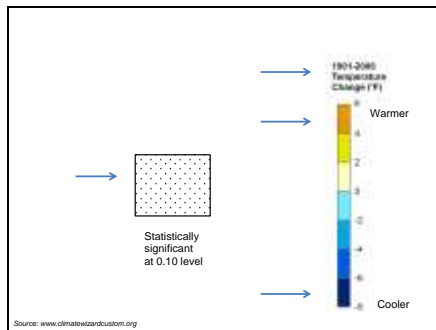
Today, I will just be focusing on the Missouri portion of the assessment area. This covers the Ozark Highlands section.

Slide 22



How has climate changed in the past?

Slide 23



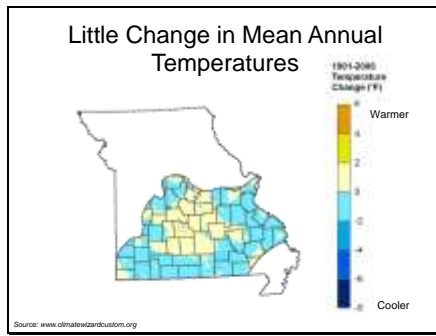
Historical measurements of climate are available back to about the start of the last century. I'm going to show you a series of maps with trends in these historical records from 1901-2006 .

Data from weather stations has been interpolated onto a grid and then analyzed for linear trends.

Yellow, orange, and red areas indicate trends toward warmer temperatures, while blue areas indicate that there is a trend toward cooler temperatures.

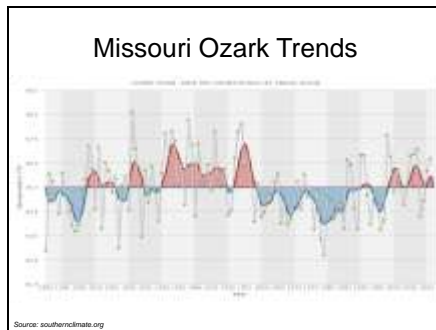
Stippling indicates that we have confidence of 90% or greater that a trend exists.

Slide 24



If we just look at mean annual temperatures over this time period, we find that temperatures have not changed considerably in the Missouri Ozarks. Some areas are slightly warmer or cooler, but these are mostly within the range of statistical noise.

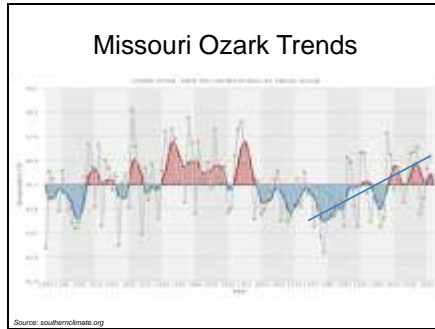
Slide 25



So, what's driving this pattern?

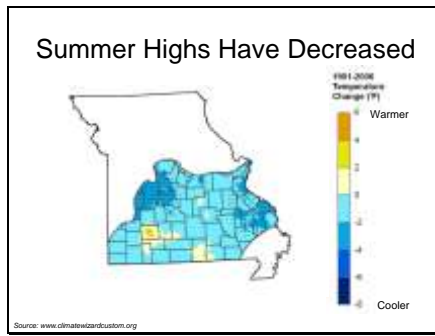
If you look at the year-to-year variation, what you see is that many of the warmest years on record were between 1920-1955, and a cooler period occurred during the 1960s and 70s.

Slide 26



More recently, temperatures have been on the upswing again.

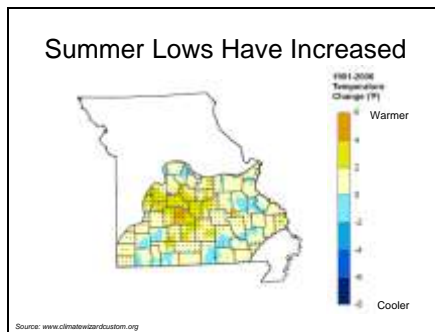
Slide 27



While there may not be any significant trends in annual temperature, there are some trends in seasonal highs and lows.

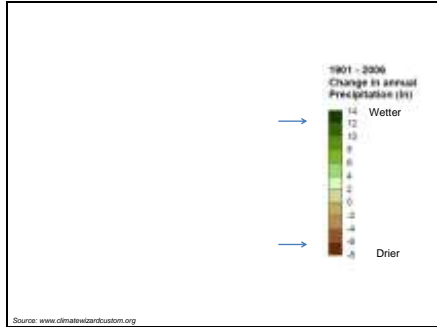
There has been a remarkable trend toward decreasing summer high temperatures in the area. There are some competing theories as to why, but one explanation is a local increase in aerosols (particulate matter in the air), which seems to be going away from tighter air quality regulations.

Slide 28



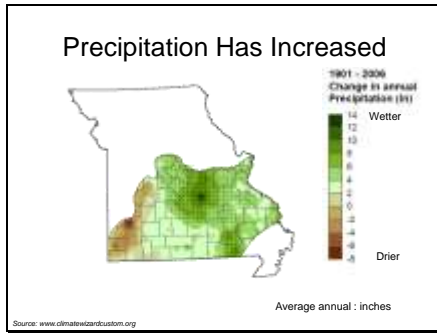
Related to this, summer low temperatures have been increasing slightly.

Slide 29



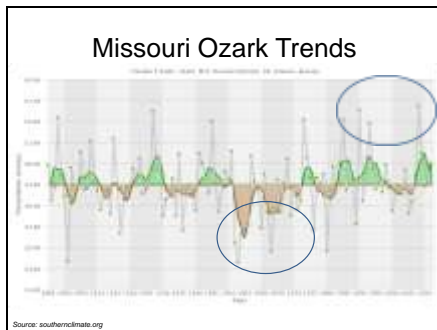
Next, I'm going to show you a series of maps that show changes in precipitation. Green indicates that things are getting wetter, while brown indicates things are getting drier.

Slide 30



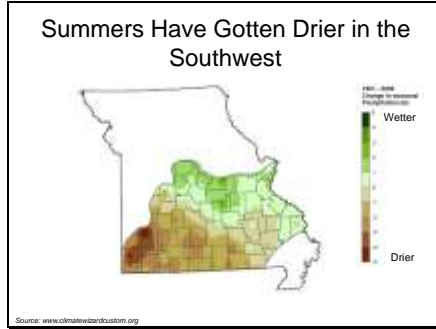
In the eastern part of the assessment area, the eastern Missouri Ozarks receiving about 4-8 inches more per year now than at the beginning of the 20th century.

Slide 31



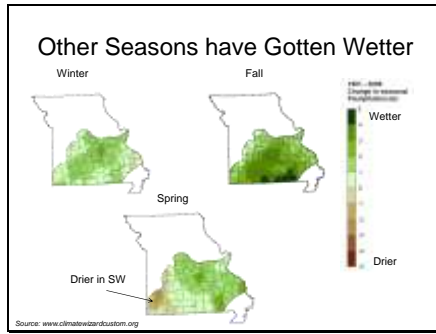
If you look back at the historical record, you see that extended periods of lower than average precipitation tend to be clustered in the middle of the 20th century, while many of the wettest years have been in the past few decades.

Slide 32



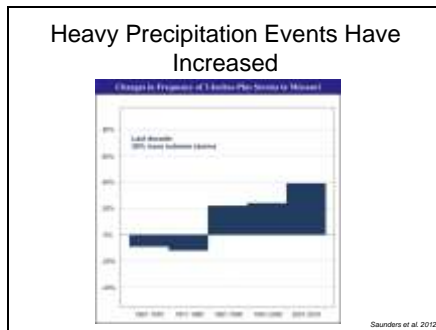
Not all seasons have changed in the same way. Summers have gotten considerably drier in the southwestern part of the assessment area.

Slide 33



Other seasons have gotten much wetter, with the exception of drier conditions in the southwest in the spring.

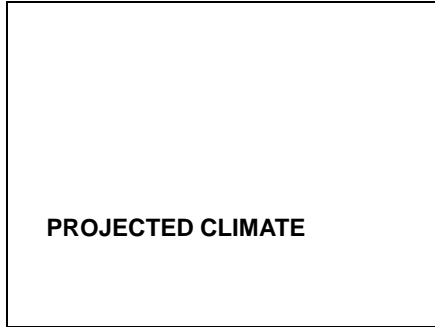
Slide 34



While more precipitation in some areas may seem good, it is important to keep in mind that more and more of this precipitation has been falling as heavy rain events, which can't always be utilized by terrestrial ecosystems.

A recent report shows that the first decade of the 21st century had 39% more 3-inch rain events compared to the 1961-1990 average.

Slide 35



What I just showed you was all based on actual measurements of climate and weather-related events.

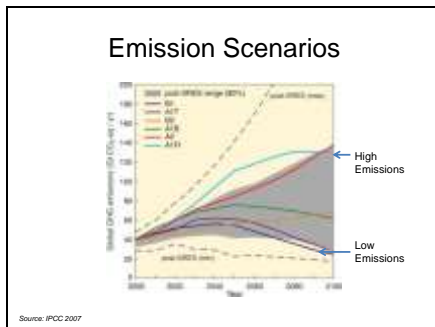
Now I'd like to switch gears and talk about how climate may change in the future.

Slide 36



We can't predict the future. Changes in population, technology, and policies will affect how much greenhouse gas emissions, and thus climate, may change over the next century.

Slide 37



However, we can make projections. In order to do this, scientists have crafted storylines about how the world may change over the next century, and then calculated greenhouse gas emissions associated with those storylines.

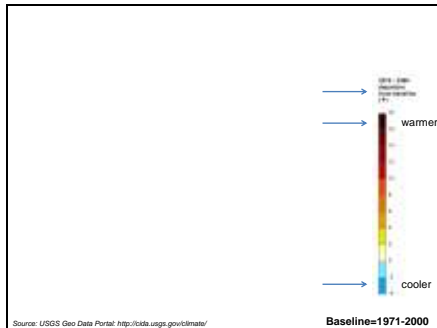
Over the next set of slides, I'm going to show you modeled projections for two emission scenarios. We chose a low-end and a high-end scenario to bracket the range of possible futures. However, it's important to note that current greenhouse gas emissions are tracking above the "high emissions" scenario.

Slide 38



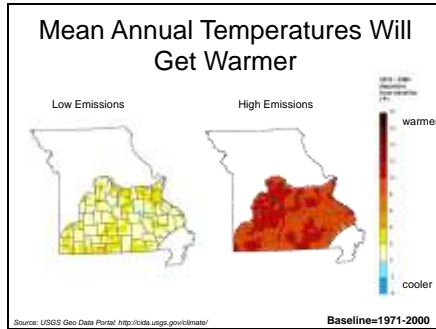
These scenarios are then incorporated into large-scale climate models. I'll spare you the details, and let's instead imagine we stepped into a time machine and can peer into the future... all the way to the end of the century.

Slide 39



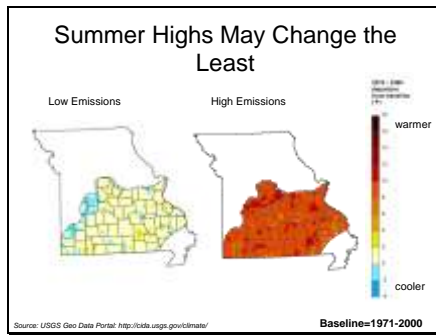
The next couple of maps show temperature projections for the years 2070-2099 compared to the average from 1971-2000. As before, "warmer" colors indicate warmer temperatures and blues indicate cooler temperatures. This is the same scale I showed you previously, but there are more reds because there are more dramatic temperature increases.

Slide 40



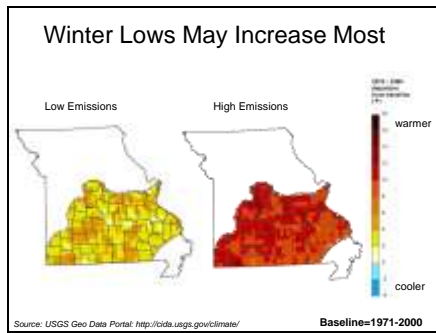
These maps show the projected average annual temperature. The low emissions scenario shows slightly higher temperatures on average, while the high emissions scenario shows an increase of 8-12 degrees F.

Slide 41



These model projections indicate that summer high temperatures will change the least, and may not change at all under the low emissions scenario.

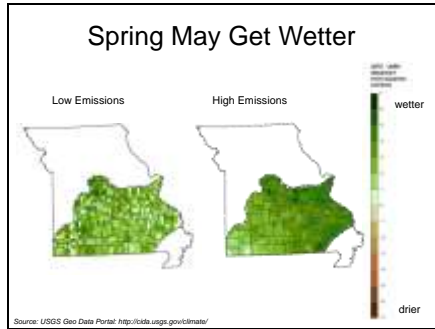
Slide 42



Increases in winter low temperatures may be some of the most dramatic.

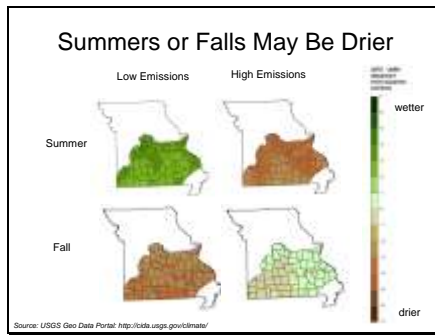
Overall, this means that there will be a greater reduction in extremely cold nights than an increase in extremely hot days. Which sound good, until you start thinking about insects, diseases, and invasive species.

Slide 43



Under both emissions scenarios, it appears that spring precipitation will increase from what it is today.

Slide 44



However, there is some uncertainty about how precipitation will change in the summer and fall. But there is a general indication that there may be a decline in available water at some point later in the growing season.

Slide 45

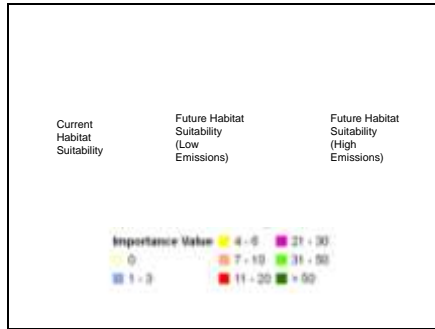
IMPACTS ON FORESTS

Changes in climate are important to understand. But, ultimately, we want to know what this means to forests.

Additional modeling has been done using the climate data I just showed you as inputs into forest impact models.

I'm going to show you some results we have so far researchers at the Northern Research Station.

Slide 46

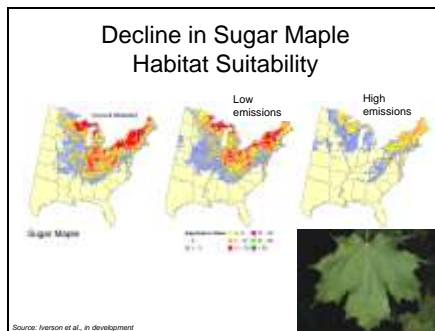


This first set of results is from Louis Iverson’s group in the Delaware, OH office.

These maps show changes in importance values (an index of species abundance).

On the left is the current habitat suitability for maple, the center shows habitat suitability under low emissions, and the right shows habitat suitability under high emissions.

Slide 47



This modeling shows that under the low emissions scenario, sugar maple habitat will likely remain stable in Missouri, and perhaps expand slightly. However, under high emissions, no habitat is projected to remain suitable in the Missouri Ozarks.

Note: this is a projection of habitat suitability not a prediction of where species will be.

Slide 48

Other “losers”

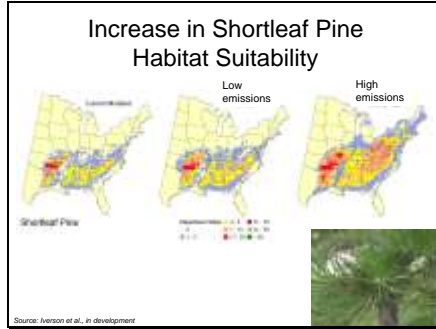
	Species
Large decrease (50% decline, or more)	pignut hickory, American basswood, scarlet oak, American beech, shagbark hickory, butternut, sugar maple, eastern white pine, Ohio buckeye, rock elm, shellbark hickory, swamp chestnut oak, swamp white oak
Small decrease (20-50% decline)	American elm, eastern cottonwood, black oak, pawpaw, chinquapin oak, bur oak, flowering dogwood, hackberry, sassafras, slippery elm, white ash, black locust, black willow, shingle oak, silver maple, black walnut, pin oak, black locust, white oak

Source: Iverson et al., in development

This same modeling was done for 77 tree species in the Missouri Ozarks. Of these, 32 species were expected to decline, but none were expected to be extirpated entirely.

Many of these include more northern species, such as sugar maple, beech, and basswood.

Slide 49



This general northward migration of habitat suitability will open up new opportunities for more southern species. Suitable habitat for shortleaf pine in the Missouri Ozarks, for example, is projected to increase under high emissions.

Slide 50

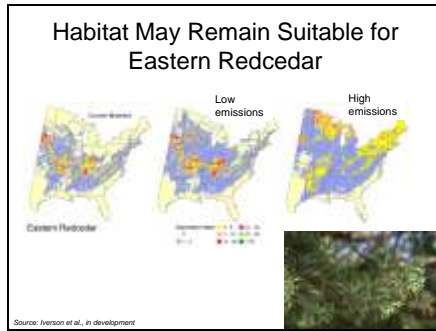
Other "winners"	
	Species
Small Increase (20-50% increase)	Blackgum, river birch, blackjack oak, eastern hophornbeam, green ash, osage-orange, post oak, red maple, yellow-poplar
Large Increase (50% increase, or more)	shortleaf pine, bald cypress, southern red oak, overcup oak, pecan, winged elm, Am. hornbeam, musclewood, chestnut oak, loblolly pine, Shumard oak, sugarberry, sweetgum, Virginia pine, willow oak
New migrants	laurel oak, longleaf pine, sourwood, cedar elm, slash pine, water oak

Source: Iverson et al., in development

Suitable habitat for 29 species is projected to increase or become newly available.

Many southern species fall into this category.

Slide 51



Finally, some species may not change considerably in abundance in the Missouri Ozarks. Eastern redcedar, while changing elsewhere, is projected to remain relatively stable in this part of the country.

Slide 52

Other “non-changers”	
	Species
Non-Changer (less than 20% change in either direction)	bitternut hickory, blue ash, black cherry, cherrybark oak, black hickory, chittamwood-gum, burrhead, boxelder, Nuttall oak, common persimmon, swamp tupelo, eastern redbud, wild plum, eastern red cedar, honeylocust, mockernut hickory, northern red oak, red mulberry, sycamore

Source: Iverson et al., in development

18 species are not supposed to change dramatically in suitable habitat.

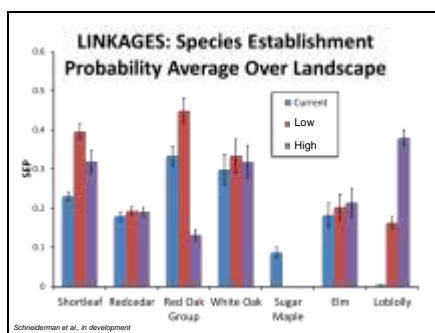
Many of these species have wide ranges and are able to persist under a wide variety of conditions, such as honeylocust, eastern redcedar and boxelder.

Slide 53

Two Additional Models	
LINKAGES <ul style="list-style-type: none"> • “Gap” model • 1/12 ha plots • 7 species groups • Nutrient dynamics simulated 	LANDIS PRO <ul style="list-style-type: none"> • Spatially dynamic model • 90 m grid • 7 species groups • Migration simulated

Two additional modeling efforts have looked at projected changes in tree species distributions in the Missouri Ozarks led by researchers at the University of Missouri and the Northern Research Station.

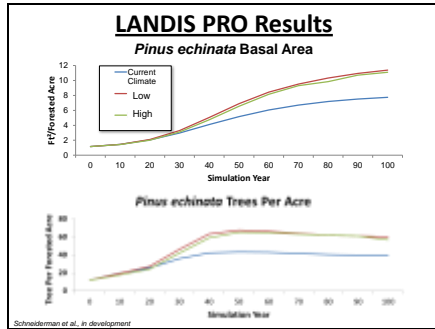
Slide 54



Model results for the LINKAGES model seem to line up well with Iverson’s results. They show a decline in sugar maple and an increase in shortleaf and loblolly pine.

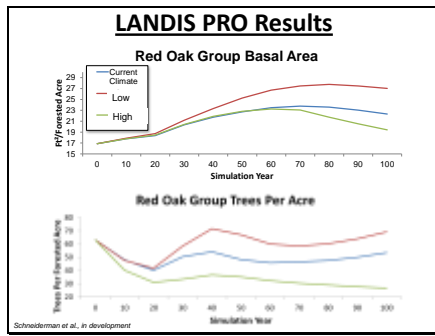
The red oak group’s fate largely depends on the model, and may increase under low emissions or decrease under high.

Slide 55



Landis Pro also shows an increase in shortleaf pine.

Slide 56



As with Linkages, Landis pro suggests a decline for the red oak group under high emissions and an increase under low emissions.

Slide 57

Other Forest Impacts

- Increased probability of wildfire by end of century
- Greater susceptibility to non-native species invasions
- More pest and disease outbreaks
- Carbon dioxide fertilization

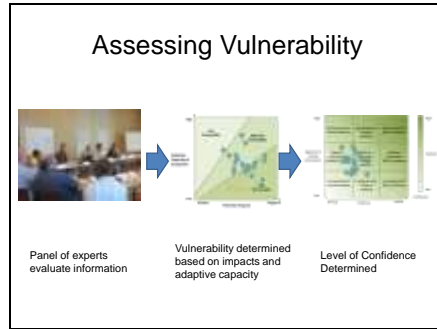
Sources: Moritz et al. 2012, Dukes et al. 2009, Lenihan et al. 2008

The results presented above are just based on changes in temperature and precipitation.

Other factors will also influence the distribution and abundance of species and will likely change with climate change.

These include: (read slide)

Slide 58



To assess how vulnerable forests in the Missouri Ozarks are to all these impacts,

- we assembled a panel of experts to evaluate the current state of our knowledge on climate change impacts in the central hardwoods region
- For 9 broad forest community types, this panel assessed whether impacts tended to be more positive or negative
 - They also assessed the adaptive capacity of the system (the ability of the system to accommodate change)
- Each expert evaluated the amount of evidence and how much that evidence tended to agree to assign a level of confidence in that vulnerability determination.

I'm now going to give you a couple of examples of what we found.

Slide 59



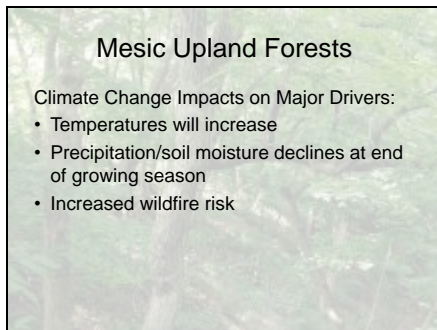
One forest community type we assessed was mesic upland forests

Slide 60



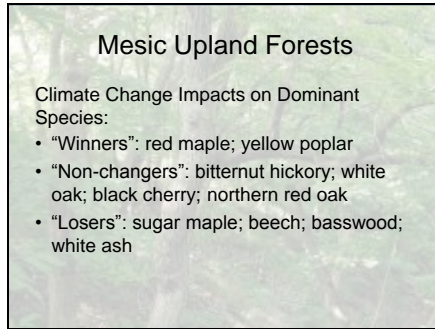
The expert panel determined that the vulnerability of this system was high.

Slide 61



Climate change will likely have negative effects on major system drivers.

Slide 62



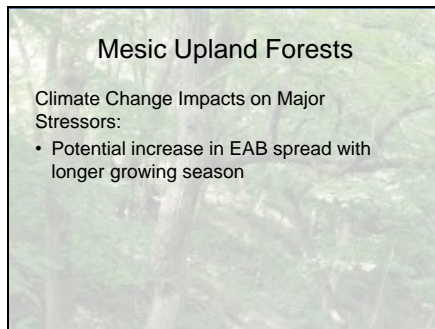
Mesic Upland Forests

Climate Change Impacts on Dominant Species:

- “Winners”: red maple; yellow poplar
- “Non-changers”: bitternut hickory; white oak; black cherry; northern red oak
- “Losers”: sugar maple; beech; basswood; white ash

Based on the modeling results, many of this community type’s dominant species are projected to decline, and few are projected to increase.

Slide 63



Mesic Upland Forests

Climate Change Impacts on Major Stressors:

- Potential increase in EAB spread with longer growing season

Climate change is unlikely to reduce any of this system’s major stressors and may increase the spread of EAB.

Slide 64



Mesic Upland Forests

Adaptive Capacity:

- Not resilient to drought, fire
- Few places on the landscape to serve as refugia

This system also has low adaptive capacity because it is not resilient to disturbances and it already occupies the coolest, wettest upland sites in the area.

Slide 65



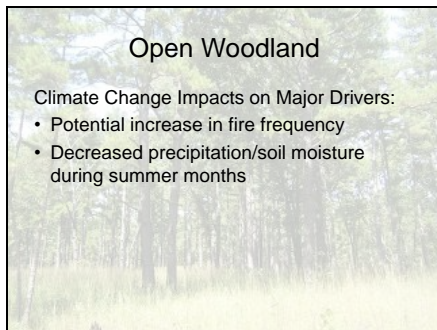
Another community type we evaluated was open woodlands.

Slide 66



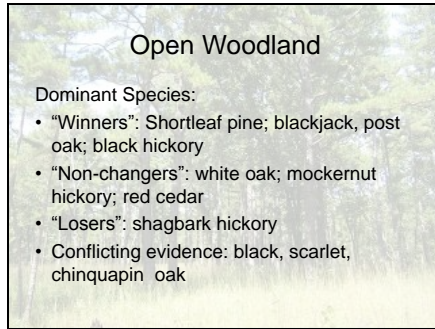
The panel determined that the vulnerability of this community to CC was low.

Slide 67



Likely climate change impacts will be generally in line with conditions that favor this community type.

Slide 68

A slide titled "Open Woodland" with a background image of a forest. The text on the slide is as follows:

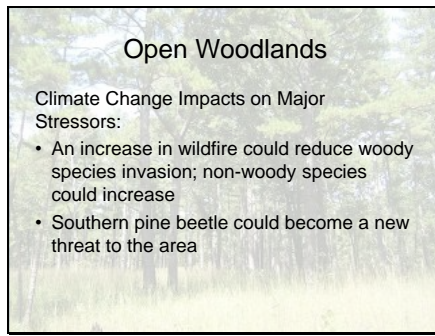
Open Woodland

Dominant Species:

- "Winners": Shortleaf pine; blackjack, post oak; black hickory
- "Non-changers": white oak; mockernut hickory; red cedar
- "Losers": shagbark hickory
- Conflicting evidence: black, scarlet, chinquapin oak

In contrast to the mesic upland systems, a number of dominant species in open woodlands are projected to increase or remain stable.

Slide 69

A slide titled "Open Woodlands" with a background image of a forest. The text on the slide is as follows:

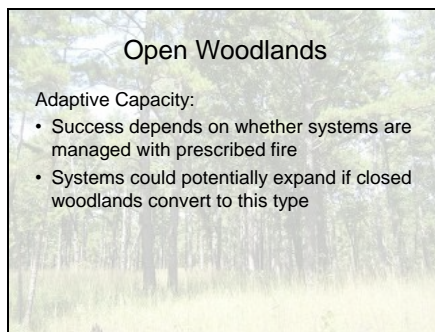
Open Woodlands

Climate Change Impacts on Major Stressors:

- An increase in wildfire could reduce woody species invasion; non-woody species could increase
- Southern pine beetle could become a new threat to the area

Some of these stressors may be reduced, while others may increase

Slide 70

A slide titled "Open Woodlands" with a background image of a forest. The text on the slide is as follows:

Open Woodlands

Adaptive Capacity:

- Success depends on whether systems are managed with prescribed fire
- Systems could potentially expand if closed woodlands convert to this type

This system's adaptive capacity largely depends on whether they are managed with prescribed fire.

Other more closed systems could convert to this type if conditions become drier and more fire-prone.

Slide 71

Other Communities Assessed

Community Type	Structural Integrity	Adaptive Capacity	Vulnerability	Evidence
Burns	Medium	High	Low	Medium-high agreement; Medium evidence
Closed Woodland	Positive	High	Low	Medium agreement; Limited evidence
Open Woodland	Positive	High	Low	Medium agreement; Medium/Limited evidence
Dry/Wetland Forest	Medium	High	Low-Medium	Medium-high agreement; Medium evidence
Flarwoods	Slightly Positive	Medium	Low-Medium	Medium agreement; Limited to medium evidence
Heath	Slightly Positive	Medium	Low-Medium	Medium-high agreement; Medium evidence
Open Woodland Forest	Medium	Medium	Medium	Medium agreement; Medium/Limited evidence
Open Woodland Forest	Slightly Negative	Medium	Medium-High	Medium agreement; Medium/Limited evidence
Open Woodland Forest	Negative	Low	High	Medium-high agreement; Medium evidence

In addition to the two community types shown here, we also evaluated 7 other community types.

Vulnerability ranged from low-high; and experts generally felt that we had a medium level of evidence to support those determinations.

Slide 72



Slide 73



Slide 74

