SCRIPT Climate Change Effects on Forests and Grasslands: What You Need to Know

1. **Title Slide**
    a. Climate Change Effects on Forests and Grasslands: What You Need to Know
2. **Introduction**
    a. The average annual temperature in the United States has increased over the last century, and most of this warming has occurred since the 1970s. In fact, each decade since the 1980s has set a new record for the warmest decade on record.
    b. The average temperature in the United States has risen more than two degrees Fahrenheit in the past 50 years. Increasing temperatures are having wide-ranging effects on forests and grasslands, including streamflow, precipitation patterns, snowpack, insects, and invasive plant species, and influencing drought, heat waves, and wildfire. These are just a few examples of the observed effects of climate change around the United States, and most effects are expected to continue and intensify during this century.
    c. Greenhouse gas emissions have been increasing and affecting the current climate. The choices humans make about land use, energy, and development will influence the future amount of greenhouse gas emissions. To project the future effects of climate change, different future emissions scenarios of greenhouse gases, also known as “pathways”, are used as inputs to climate models. Each climate model, in turn, simulates the climate system differently. Future emissions scenarios combined with different climate models result in a range of temperature and precipitation outcomes from warmer to much hotter, and drier to wetter. In general, higher emissions scenarios or pathways lead to projections of more severe changes, and lower emissions scenarios or pathways lead to projections of less severe changes.
    d. The range of emissions scenarios and outputs from climate models represents most of the uncertainty in future climate projections. The climate is certainly changing and will continue to change, but because we still have some unknowns about the future, we need to work with a plausible range of future climates that incorporates the variety of emission pathways and model projections.
3. **Benefits/Stresses**
    a. Under the right set of conditions, some ecosystems may benefit from climate change. These benefits may last only for a few decades, or they may last longer. However, it is more likely

that climate change will worsen existing stressors in an ecosystem or add new stressors. Often, these benefits and stressors that we identify are part of personal values and beliefs about how ecosystems should look and function. It is critical to think about where benefits and stresses may occur, so we can be ready to take advantage of climate change benefits and overcome challenges from climate change stressors.

4. Effects

a. There are many ways to describe the effects of climate change on forests and grasslands. In this module, the major effects on forests and grasslands are grouped into four broad categories: water, vegetation, wildlife, and disturbances. Each category may include both stresses and benefits to ecosystem health and function. The effects may not occur in isolation, and are, in fact, very likely to interact with each other. Let's begin with water.

5. Water/Precipitation

a. Different regions across the United States have already experienced changes from historical precipitation; some areas are receiving more precipitation or more heavy precipitation, and others are becoming drier. Precipitation in many places has become more variable, sometimes obscuring clear trends. Changes in precipitation patterns and amounts affect soil moisture, groundwater levels, and wildfire risk.

b. Projections of future precipitation show high variability, and sometimes different models or emissions scenarios project opposite patterns in rainfall during the same season. Regions that are projected to experience more annual precipitation in the future may not necessarily benefit, because more of that precipitation is expected to fall during intense storms. This is already occurring in some areas, resulting in more frequent flooding and erosion. Some forests are experiencing longer dry periods between heavy precipitation events. These dry periods can result in water stress in forests, and the heavy rains may not help reduce water stress because more precipitation flows directly into streams instead of filtering into the soil.

6. Water/Snow Cover

a. In the last few decades, snow cover across much of the United States has decreased in depth, extends over a smaller area, and melts sooner in the spring. Changes in snow cover and snowmelt have wide-ranging effects. Less snowpack combined with earlier melting provides less insulation for plants and soil, exposing them to frosts and freezing temperatures. Early snowmelt also alters the timing of runoff into streams, with large flows

happening earlier, followed by diminished flows late in the growing season. Low flows in summer and fall can lead to water stress for plants, which can lead to increased risk of insect infestations and wildfire, and affect soil processes. Lower flows late in summer also result in lower water volume and higher temperatures in streams, which may negatively affect fish populations.

7. Water/Flow

a. Together, changes in precipitation patterns and snow cover affect the timing and amount of runoff and streamflow. In particular, rain-on-snow events, when rain falls on snow, are projected to become more frequent and intense as temperature increases. Warmer temperatures shift winter precipitation from snow to rain, and the warmer rain filters into the snowpack, causing it to melt, increasing runoff and the risk of flooding and erosion.

b. Decreases in summer seasonal flows and increases in flash floods and short periods of high flows from more intense storms are projected effects of climate change during this century.

8. Water/Sea-level Rise

a. Oceans absorb over 90 percent of the extra heat in the atmosphere from human-caused emissions. As the water heats up, it expands, contributing to the rise in sea level. Global sea levels have risen 8 inches since the 1880s; and since 1992, global sea level has risen twice as fast as the long-term trend. By the end of the century, global sea level is projected to rise by one to four feet. This rise, along with the projections for more coastal storms, will increase the risk for erosion, storm surge, and flooding events, affecting coastal ecosystems and infrastructure.

9. Vegetation/Growing Season

a. The frost-free season, often used to define the length of the growing season, has lengthened around the country since the 1980s, with the largest increase observed in the West. The first freeze is happening later in the fall, and the first thaw is happening earlier in the spring. The increase in length of the frost-free and growing seasons is expected to continue in this century.

b. Earlier snowmelt and springtime has led to earlier emergence of leaves, or leaf out, and earlier flowering in some plants. Longer warm periods mean that plants have a longer time to grow, which may increase the productivity of forest and grasslands if the plants have adequate water and nutrients. This could be a beneficial effect of climate change.

However, there may also be some negative aspects to a longer growing season, click on the box to learn more.

10. Vegetation/Carbon Dioxide (CO_2) Fertilization

a. Plants use sunlight, water, carbon dioxide, and nutrients to make the carbohydrates necessary for growth, releasing oxygen as a byproduct. This is the process known as "photosynthesis." Atmospheric carbon dioxide levels are increasing because of human use of fossil fuels, and some of this extra carbon dioxide in the atmosphere can be used by plants. More carbon dioxide may increase photosynthesis and water use efficiency, creating more biomass. This is known as "carbon dioxide fertilization."

b. In many plants, carbon dioxide fertilization may be only temporary, elevating photosynthesis for a short time until the extra carbon dioxide no longer produces more biomass. Increased photosynthesis is also dependent on nutrient and water availability, so carbon dioxide fertilization will not be as effective in areas without an adequate supply of these resources. Sites with suitable resources are better able to support carbon dioxide fertilization, and certain plants are better able to respond to carbon dioxide fertilization, regardless of site. This all means that carbon dioxide fertilization will be beneficial for some, but not all, plants and forests.

11. Vegetation/Water Use

a. After several decades of wet conditions, drought events are increasing in many places around the country, particularly in the West. With increases in heat waves and longer periods of higher temperatures and lower soil moisture, many trees become stressed and may even die. These droughts and prolonged dry periods can damage or kill trees during insect outbreaks, because insects thrive on trees already weakened from low water availability. Dead and dying trees increase wildfire risk by temporarily increasing downed and standing fuel, which are especially combustible during droughts.

b. Tree mortality from drought, insects, wildfire, or interactions between these effects, can alter the species composition and structure of a forest. More frequent and severe droughts are projected for this century in the southern and western U.S., and it is likely that tree mortality will also increase, bringing more changes to forests in the future.

12. Vegetation/Habitat Range Shifts

a. As temperature increases and precipitation changes, the range of suitable habitats for many plant species will also change. For example, the suitable habitat range of some plant species

may shift northward or upslope to higher elevations, or shifts may even follow changing moisture conditions. Species growing outside ideal habitats will not immediately die off; instead, these species may experience more stress, reductions in productivity, or difficulty regenerating.

b. The largest initial responses of plants to habitat changes may be seen in the establishment of seedlings. Populations that live at the southern edge or lower elevation of their range may experience decreased establishment and growth of seedlings. Even as this is happening, populations living at the northern edge or higher elevations of their range may experience better establishment and growth of seedlings. However, forest fragmentation is already slowing natural rates of migration, and due to the speed at which climate change is occurring, it appears unlikely that most tree species will be able to migrate as fast as their suitable habitat is shifting.

13. Wildlife/Habitat Range Shifts

a. Similar to vegetation, the current habitats of many wildlife species may become unsuitable with further temperature increases and changes in precipitation. The ranges and distributions of many wildlife species are already shifting northward and up in elevation, and these shifts are projected to continue. For species that may not be able to migrate to more suitable habitat, their range and distribution may contract.

b. Habitat connectivity is an important consideration in the distribution and movement of wildlife. Human development typically fragments the landscape, making it more difficult for wildlife to safely move to new places as suitable habitat shifts. As climate change alters ecosystems and humans continue to fragment the landscape, wildlife may need to pass through unsuitable habitat to avoid humans and reach new areas, or they may be forced to migrate through developed landscapes. Wildlife populations that cannot find safe corridors to new habitats may become isolated and experience declines.

14. Wildlife/Phenology

a. Phenology refers to the timing of biological events, such as flowering, migration, and breeding. Sunlight and temperature influence phenology, acting as the primary cues to begin these natural events.

b. Higher temperatures have already increased the length of the growing season. Longer growing seasons affect natural events that use temperature as cues, and as a result some

migrations, breeding events, and pollination patterns are happening earlier than historically observed.

c. Biological events cued by temperature or sunlight often depend on each other. If temperature cues are changing and sunlight cues are staying the same, a mismatch could develop between the two dependent biological events. For example, insects cued by temperature may emerge earlier than bird migrations cued by sunlight. This could result in asynchrony, and the migrating birds may arrive too late for important food sources. Phenological mismatches are already happening around the country and can have cascading effects throughout the ecosystem.

15. Disturbances/Insects

a. Disturbances from insects are a part of natural forest cycles, but insect outbreaks have increased in the last few decades as temperatures have increased and droughts have become more frequent. For example, between 2000 and 2012, 46.1 million acres in the western United States were affected by western bark beetles.

b. Minimum temperatures in winter have been rising across the United States, allowing insects, like bark beetles, to migrate north and to higher elevations, expanding into previously unaffected areas. Temperatures are warm enough for bark beetles to survive over the winter, and two-year lifecycles are often taking only one year to complete. Increased populations of bark beetles and other insects, like the nonnative hemlock woolly adelgid, are threatening the health and vigor of many forests.

16. Disturbances/Invasives

a. Invasives are nonnative species that are able to establish within native habitats, where they may alter how the ecosystem functions. Invasives can decrease native biodiversity and change the species composition of ecosystems. They can be plants, animals, diseases, or insects, but the focus here is on invasive plants. Invasive plants compete for resources with native species, reduce habitat for some wildlife species, and can affect soil nutrient cycling, water use, and disturbance patterns like wildfire regimes.

b. Observed and projected climate change effects such as higher temperatures, earlier springs and snowmelt, reduced snowpack, changes in disturbance patterns, and elevated carbon dioxide, also influence invasive species establishment and spread.

c. In some cases, the current ranges of some invasive species may actually contract with climate change, but there is widespread concern that the changing climate will more often

result in faster spread of invasives due to more frequent disturbances and short-term stress in native ecosystems. Invasives are spreading fast in arid ecosystems, and there is an especially high risk of invasive species establishment in northern ecosystems and mountainous regions because cooler temperatures limited invasive establishments in the past.

17. Disturbances/Wildfire

a. Climate and fuels are important drivers of wildfire in forest and grassland ecosystems. Climate influences the weather conditions that support fire occurrence, and the fuel amount and arrangement influence fire intensity and extent.

b. Drought conditions and increased temperature generally increase fire risk, although this varies by forest type, region, and fire regime. As a result of longer growing seasons and altered precipitation, the length of the fire season and the annual area burned have been increasing in the western United States and are expected to continue to increase in the future. A higher risk of fire poses a threat to the wildland-urban interface—places where people live and build near natural areas prone to wildfire.

c. Past and current fire management practices, combined with climate change, affect the risk, behavior, and severity of fire. The 1900s were dominated by a policy of fire suppression, and fires were fought and controlled in nearly all public and private lands. Decades of this policy allowed fuels to accumulate on the forest floor, fire no longer killed seedlings, and young trees were able to establish and grow in older stands. Although fuel reduction practices such as prescribed burning are now common, the accumulation of fuels and young trees that act as ladders to carry the fire into the canopy has contributed to an increase in large, severe fires in some areas. The connection between fire and fuels is an important consideration for forests, primarily dry forests in the western United States.

18. Conclusion

a. Climate change will affect forest and grassland ecosystems in many different ways. These effects are not confined to categories; instead they interact with and affect one another, often further increasing the impact of climate change on ecosystems.

b. This module has provided a very general overview of major effects and interactions of climate change. There are an increasing number of scientific reports and assessments about climate change effects and vulnerabilities in forests and grasslands across the United States.

c. Where do you live and work? Have you seen any of these changes in your local forests or grasslands? What are some of the resources or conditions there that are particularly vulnerable?