CLIMATE CHANGE TRENDS AND STRATEGIES

Uwharrie National Forest

Overview

For the Uwharrie National Forest in central North Carolina and for much of the southeastern United States, climate variability and weather events such as floods, heat waves, droughts, tornadoes, hurricanes, and lightning storms have long been part of the natural environment. From a climate perspective, the Southeast has some of the warmest temperatures in the United States generally receives more rainfall than any other region in the United States, and experiences many extreme climate events, (US Global Change Research Program, 2001). Hurricanes are a threat from both the Gulf and Atlantic coasts, tornadoes and other intense storms can occur throughout the Southeast, and weather disasters from floods to freezes can cause extreme damage.

These climate variables and associated disturbances have influenced the current makeup and geographical distribution of many ecological communities and landscapes across the South. However, the increasing changes in climate and disturbances projected for the future are expected to lead to significant alterations in our forests and the services they provide (U.S. Climate Change Science Program, SAP 4.3, May 2008). While some ecosystems may adapt and alterations can sometimes be beneficial, the rate of change is predicted to exceed the ability of other systems to migrate or adapt and many changes are expected to be viewed as detrimental. In light of the importance of this emerging issue, new management strategies are being considered for forest ecosystems across the South.

Some of the challenges facing national forests in developing strategies for addressing climate change are the uncertainties about the direction of change, especially at local levels, and how natural ecosystems will respond to future natural and human-induced pressures. Forest Service scientists have been studying various aspects of climate change on forests for many years, and the Forest Service Chief has identified climate change as one of three overarching challenges facing the agency. Yet, our knowledge of how plants and ecosystems respond to the threats of a changing climate and how to react appropriately at local levels where management actions are most effective is still very limited (Solomon, 2008). Uncertainties about outcomes will require flexibility, and land management strategies based on current or historical conditions may need to be adjusted or replaced with approaches that support adaptation to changing conditions (USDA Forest Service, October 2008).

Southern forests provide a wealth of services and products including clean water, clean air, biological habitats, recreation opportunities, carbon storage, timber, specialty commodities, fuel, and aesthetic and cultural values. Scientists have indicated that a changing climate can affect the future biodiversity and alter the function of the forest ecosystems that support these services and products (U.S. Climate Change Science Program, SAP 4.3, May 2008). Species distributions may shift, some species are likely to decline while others expand, and whole new communities may form. Forest productivity may be reduced in some instances due to a decline in photosynthesis caused by increased ozone, and productivity may be enhanced in other settings where elevated levels of carbon dioxide (CO_2) have a fertilizing effect on overall tree growth. Anticipated increases in extreme weather events (such as with droughts and hurricanes) outside the historic range of natural variability may alter the frequency, intensity, duration, and timing of disturbances such as fire, non-native invasive species, and insect and pathogen outbreaks. Changes in forest composition and growth may also have associated impacts on wildlife habitats, the supply of wood products, specialty markets, and recreational opportunities (U.S. Climate Change Science Program, SAP 4.4, June 2008; Marques, 2008).

In developing management strategies to deal with a changing climate, it has been recognized that forests can play an important role in both mitigating and adapting to climate change. Mitigation measures focus on strategies such as biological carbon sequestration (Johnsen et al, 2001), ways to increase carbon stored in wood products, ways to provide renewable energy from woody biomass to reduce fossil fuel consumption, ways to reduce greenhouse gas emissions, and other ways to reduce environmental footprints. Adaptation measures address ways to maintain forest health, diversity, productivity, and resilience under uncertain future conditions. Adaptation and mitigation activities must also complement each other and balance with other ecosystem services (USDA Forest Service, October 2008).

Forest Service research activities in the coming years are expected to help both public and private land managers better understand changing conditions and determine appropriate management approaches for both adaptation and mitigation. The global change research approach that will guide Forest Service Research and Development for the next decade will not only address enhanced ecosystem sustainability (adaptation) and increased carbon sequestration (mitigation) but will also provide decision support models for land managers and facilitate scientific collaboration and technology transfer (USDA Forest Service, February 2008).

In light of the evolving research and extent of unknowns regarding climate change impacts, this discussion focuses on (1) our current understanding of what the potential climate change-related stresses are that may impact Uwharrie National Forest, (2) which factors may influence desired conditions identified in the Forest Plan, and (3) what appropriate management strategies and future research studies are being developed to address climate change and support Plan objectives. At this time, the science of climate change modeling is at the stage of stepping down global models to regional scales (Davis, 2007), so a combination of national projections and regional-level climate trends for the southeastern United States will be used as the most reliable context for describing expected climate changes and impacts. Specifics regarding many mitigation measures, such as the appropriate calculations for carbon offsets and how to consider carbon sequestration rates, are still being developed, so most of our focus at the forest level for now will be on using management options to improve resilience and adaptability of native ecosystems under changing conditions. Then, over the 15-year life of the Plan, as issues are better understood and appropriate measures are identified, climate change strategies can be adjusted through the adaptive management process.

Southern Region Climate Change Trends and Expectations

Across the country, warming temperatures, altered precipitation patterns, rising sea levels, and increases in the number and intensity of extreme weather events are already causing observed ecological responses across the United States (U.S. Climate Change Science Program, SAP 4.3, May 2008). Although there are variations by region, overall temperatures across the nation warmed during the 20th century, with 11 of the 12 years from 1995-2006 among the warmest since instrumental record keeping was started in 1850 (U.S. Climate Change Science Program, SAP 4.4, June 2008; IPCC, 2007). Precipitation patterns and distribution also vary regionally, but the total annual precipitation in the contiguous United States has increased 6.1 percent over the last century, with about half of the increase attributed to increased storm intensity (U.S. Climate Change Science Program, SAP 4.4, June 2008: Karl and Knight, 1998). Warming temperatures contribute to sea level rise, and relative sea levels have risen 3-4 mm per year in the Mid-Atlantic states and 5-10 mm per year in the Gulf states (U.S. Climate Change Science Program, SAP 4.4, June 2008: U.S. Environmental Protection Agency, 2007).

Over the past decade, a number of models have been developed to simulate climatic effects anticipated in the future. These scenarios are based on historical data, trends, and analysis of different plausible assumptions. While climate model simulations are continuing to be developed and refined, climate projections typically do not yet identify expected conditions below the regional scale in the US. In the report by the US Global Change Research Program on Climate Change Impacts on the United States (2001), the two principal models that were found to best simulate future climate change conditions for the various regions across the country were the Hadley Centre model (developed in the United Kingdom) and the Canadian Climate Centre model. Unless otherwise noted, the following discussions of climate change expectations for the southeastern United States are based on findings from the 2001 US Global Change Research Program report and more recent projections in the U.S. Climate Change Science Program Reports (SAP 4.3, May 2008; SAP 4.4, June 2008).

For some aspects of climate change, virtually all models agree on the types of changes to be expected for the southern region of the United States:

- The climate is going to get warmer, especially warmer minimum winter temperatures. Both the Hadley and Canadian models show increased warming in the Southeast but at different rates [see inset on Future Climate Scenarios for the Southeast]. Overall regional temperature changes are projected to be equivalent to shifting the climate of the southern US to the central US and the central US climate to the northern US.
- The heat index, which is a measure of comfort based on temperature and humidity, is going to rise. The principal climate model simulations agree that the heat index will increase more in the Southeast than in other regions of the United States. By 2100, the heat index under the Hadley model is projected to increase by as much as 8-10°F and by over 15°F in the Canadian model. The Northeast may feel like the Southeast does today, the Southeast is likely to feel more like today's south Texas coast, and the south Texas coast is likely to feel more like the hottest parts of Central America.
- Threats to coastal areas will increase, including rising sea levels, beach erosion, subsidence, salt water intrusion, shoreline loss, and impacts to urban development.

- Precipitation is more likely to come in heavy, extreme events.

For other aspects, models tend to differ on expectations. The Southeast is the only region where climate models are simulating large and opposite variations in precipitation patterns over the next 100 years. The Canadian model projects more extensive and frequent droughts in the Southeast, starting with little change in precipitation until 2030 followed by much drier conditions over the next 70 years. The Hadley model, in contrast, suggests there will be a slight decrease in precipitation over the region during the next 30 years followed by increased precipitation. There is also uncertainty over the extent of effects of El Nino and La Nina cycles. El Nino events typically result in cooler, wetter winters in the Southeast and fewer Atlantic tropical storms, while La Nina events tend to have the opposite effects with warmer, drier winters and more hurricanes.

Unexpected interactions among multiple disturbances happening at the same time add to the level of uncertainty. For example, tree growth is generally projected to be stimulated by increases in CO_2, but the stimulation is dependent on soil nutrition (Oren et al, 2001). Furthermore, water and nutrient stress can weaken tree health leading to insect infestations or disease, which in turn promotes future fires by increasing fuel loads and further weakening tree health (Marques, 2008).

Based on current projections, the following discussion highlights some of the potential impacts of a changing climate on forests in the southeastern US.

Future Climate Scenarios for the Southeast

<u>Warmer temperatures:</u>

Maximum summer temperature increase:
Hadley model = 2.3° F (2030)
Canadian = 5° F (2030), 12° F (2100)

Mean annual temperature increase:
Hadley = 1.8° F (2030), 4.1° F (2100)
Canadian = 3°F (2030); 10° F (2100)

<u>Higher summer heat index (average increase):</u>

Hadley model = 8-15° F (2100)
Canadian model = 15° F (2100)

<u>Moisture changes:</u>

Intensified El Nino & La Nina phases as CO_2 increases.
Hadley = 20% increased moisture
Canadian = decreased moisture; droughts

<u>Increased extreme weather events:</u>

Droughts, floods, hurricanes, tornadoes, freezes, winds, ice storms, heat waves.

<u>Higher sea levels for Atlantic & Gulf coasts:</u>
Hadley = 8-12 inch rise (2100)
Canadian = 20-24 inch rise (2100)

<u>Forest productivity</u> – In general, biological productivity of southeastern forests will likely be enhanced by increased levels of CO_2; however the extent of growth stimulation is proportional to soil nitrogen availability, and southern forests are often nutrient impoverished due to past land use. Limits on water availability may also offset CO_2 benefits if there is a decline in precipitation or if there is greater moisture stress due to high air temperatures. Without management adaptations, simulations using the Hadley model show pine forest productivity will likely increase 11% by 2040 and then exhibit a declining trend to an 8% increase by 2100 compared to 1990 productivity estimates. Hardwood productivity will likely continue to rise, with projections of a 22% increase by 2040 and 25% by 2100. This shift in productivity could have significant effects in the South where pines account for a big part of the region's forest

industry and much of the nation’s softwood inventory. Forest productivity increases may be offset, however, by escalating damage from forest pests and more extreme weather disturbances.

Forest pests – The potential for a changing climate to increase the distribution of forest pests and diseases is a concern, particularly for pests that already cause widespread damage such as Southern pine beetles. Higher winter temperatures are expected to increase over-wintering beetle survival rates, and higher annual temperatures will produce more generations each year leading to increased beetle infestations. Other factors, however, complicate projections of future infestation levels. Field research has demonstrated that moderate drought stress increases pine resin production thus reducing colonization success, while severe drought stress reduces resin production and increases pine susceptibility to beetle infestation. Insufficient evidence currently exists to predict which of these factors will control future beetle populations and impacts (McNulty et. al., 1998).

Fires – Fire frequency, size, intensity, and seasonality are directly influenced by weather and climate conditions. Nationwide projections show seasonal fire severity is likely to increase by 10% over the next century, with possibly larger increases in the Southeast. At least two ecosystem models run under the Canadian climate change scenario suggest a 25-50% increase in fires, and a shift of some southeastern pine forests to pine savannas and grasslands due to moisture stress. Under a hotter, drier climate, an aggressive fire management strategy could prove critical to maintaining regional vegetation patterns.

Shifts in major vegetation types for the Southeast – The broad variety of ecosystem types found across the Southeast ranges from coastal marshes to mountaintop spruce-fir forests. Although the South is one of the fastest growing population regions in the country, forests are common in many parts of the Southeast, with forestland covering half or more of most states. Potential changes in vegetation distribution due to climate change vary with different model scenarios. Under the Hadley model, forests remain the dominant natural vegetation in the Southeast, but the mix of forest types changes. Under the Canadian model, savannas and grasslands expand and replace parts of the southeastern pine forests along the coastal plain due to increased moisture stress. However, biodiversity predictions with these and other theoretical models have limits and may underestimate local conditions or fail to adequately take into account genetic variability, selection pressure, or management intervention. Although useful within certain contexts, forecasts of biodiversity changes are especially challenging and have to account for multiple causes of change (including human activities), effects of dispersal and migration rates, dynamic process such as fire, take into account various mechanisms of persistence, and be adequately validated (Boykin, et al., 2007). While current climate conditions now associated with southeastern forests are expected to change, the assemblages of species that will occur naturally under climate change is still unknown and will require more detailed modeling for biodiversity forecasts.

Weather-related stresses on human populations – Low-lying Gulf and Atlantic coastal areas are particularly vulnerable to flooding. With floods already the leading cause of death from natural disasters in the Southeast, increased flooding from more active El Nino/La Nina cycles could have greater adverse impacts. Even if storms do not increase in frequency or intensity, sea level rise alone will increase storm surge flooding in virtually all southeastern coastal areas. Another concern is the prolonged effect of elevated summertime heat events, which coupled with drought conditions, not only causes elevated heat stress to humans but also increases smog levels.

Increased forest disturbances – Increases in extreme events and changes in disturbance patterns may have more significant impacts, at least in the near future, than long-term changes in temperature or precipitation. Natural disturbances that may be associated with climate change include hurricanes, tornadoes, storms, droughts, floods, fires, insects, diseases, and non-native invasive species. Although disturbances are a natural and vital part of southern ecosystems, it is the change in frequency, intensity, duration, and timing exceeding the natural range of variation that is a concern (Marques, 2008). Multiple disturbances interact and further exacerbate damages. Hurricanes can cause severe disturbance that not only results in direct loss of biological communities and habitat, but the widespread damages can also shift successional direction leading to higher rates of species change and faster biomass and nutrient turnover. Invasive species and insect pests often have high reproductive rates, good dispersal abilities, and rapid growth rates enabling them to thrive in disturbed environments.

Water stresses – The difficulty in predicting whether precipitation will increase or decrease in the Southeast over the next 30-100 years extends to uncertainties over future water quantity and quality conditions. Current water quality stresses across the southern region of the country are primarily associated with intensive agricultural practices, urban development, and coastal processes such as saltwater intrusion. Although water quality problems are generally not critical under current conditions, stresses are expected to be more frequent under extreme conditions, particularly in low stream-flow situations associated with droughts. Under the Hadley model, stream flow in the Southeast has been projected to decline as much as 10% during the early summer months over the next 30 years. The Chattahoochee and Tombigbee River basins are projected to have decreased water availability over the next 50 years, and as stream flow and soil moisture decrease, agricultural fertilizer applications and irrigation demands tend to increase creating further stress and conflicts over competing uses. Parts of the Southeast that depend more on ground water are particularly vulnerable to depletion of aquifers, which can take centuries to recharge after chronic drought conditions (Hoyle, 2008).

Outdoor recreation – Outdoor recreation opportunities are likely to be impacted by climate change but would vary by location and activity. Higher summer temperatures could extend summer activities such as swimming and boating but may also reduce other outdoor activities such as hiking and trails-use in hot, humid sections of the South. Warmer waters would increase fish production and fishing opportunities for some species but decrease fishing for other cold water species. Summer recreation activities are likely to expand in cooler mountainous areas as temperatures warm along the coastal plain and lowland elevations. Skiing opportunities are likely to be reduced in the South, and some marginal ski areas may close due to fewer cold days and snow events.

Threats to coastal areas. Sea level rise is regarded as one of the more certain consequences of increased global temperatures. During the past 100 years, average sea level rose 4-8 inches and is projected to rise an additional 19 inches by the year 2100 (International Panel on Climate Change, 1996). Large cities such as New Orleans, Charleston, and Houston are already impacted by frequent and intense flooding. Low-lying marshes and barrier islands off the Southeast coast are considered particularly vulnerable to inundation. Based on current projections of sea-level rise, many southeastern coastal areas will loose shoreline as well as coastal wetlands and estuaries. In some areas, forests will decline due to saltwater intrusion. Storm surge is also likely to intensify as sea level rises and barrier protections are lost. Even if the frequency and intensity of hurricanes do not increase, these storms are expected to be more damaging when making landfall due to changes in coastal landforms.

Key Climate Change Factors for Uwharrie National Forest

Based on current projections, the primary regional-level effects of climate change most likely to occur in the Southeast include (1) warmer temperatures and a rising heat index, (2) moisture changes, (3) rising sea levels and coastal erosion, and (4) increased extreme disturbance events. Based on current climate model projections and research (including the report on Adaptation Options for Climate-Sensitive Ecosystems and Resources (SAP 4.4, June 2008) produced by the U.S. Climate Change Science Program where the Uwharrie National Forest was chosen as one of the case studies in the assessment), the climate change factors that appear most likely to affect the Forest and impact desired conditions in the revised Forest Plan are ecological and weather-related disturbances as described below:

- Projected increase in frequency of intense storms,
- Projected increase in wildfire risks, and
- Projected increase in outbreaks of insects, diseases, and non-native invasive species.

These disturbance factors and the potential impacts on desired conditions for the Uwharrie National Forest are described below.

Increased extreme weather events

Common weather events such as droughts, tornadoes, heat waves, wind storms, flooding, occasional ice storms, and warm winter days that cause untimely bud break may be influenced by climate change. Over the past 100 years, the occurrence of intense precipitation events has increased across the Southeast, and this trend is expected to continue (Marques, 2007). The rolling topography, erosive soils, and typically high annual precipitation rates on the Uwharrie National Forest make more frequent and extreme storms, floods, heat waves, and droughts a potential concern for achieving desired conditions.

Impacts from extreme weather events could include changes in the composition and diversity of desired ecosystems; destruction of habitat; timber loss; increasing damage to infrastructure such as trails, facilities, and roads; and loss of recreation opportunities. Disturbances that exceed the historic range of natural variation can change the makeup, structure, and function of forests and could affect a number of desired conditions. Heavy rains and higher flood levels can affect maintenance and structural integrity of built infrastructure and slow progress toward improvements. More frequent and extensive wind damage can increase downed trees and contribute to increased fire risk. Damage to aquatic systems from erosion, downed trees, and inundation from flooding can change streamside habitats, affect aquatic life, and impact proper functioning of stream channels. These disturbances could affect achieving Plan objectives for aquatic habitat restoration and introduction of rare species such as mussels. Overall, increasing weather-related disturbances can divert limited Forest staff and funding to recovery efforts for extended periods of time and delay progress toward desired conditions or require reconsideration of desired conditions to allow for a more dynamic resilience.

Fire

One of the natural disturbances that is an integral part of many southern forests is fire. Prior to the mid-20th century emphasis on fire suppression, a natural cycle of fire burned through native ecosystems across the Forest, generally at a low intensity and at varied return intervals. Many of the native ecosystems that make up the Uwharrie National Forest are adapted to or dependent on some level of periodic fire. These include commonly occurring native ecosystems such as longleaf pine forests, shortleaf pine/oak woodlands, and oak-hickory forests as well as the more rare glades and barrens and mafic hardpan woodlands. Loblolly pine forests are also maintained by fire. While prescribed burning is used as a management tool to maintain or restore historic fire regimes, warmer temperatures, more frequent droughts, and more extensive disturbances can change conditions and accelerate fuel loading and higher fire hazards.

Fire frequency, size, intensity, seasonality, and severity are highly dependent on weather and climate. As noted earlier, model results predict that seasonal severity of fire hazard is likely to increase by 10 percent over much of the United States during the 21st century, with possibly larger increases in the Southeast (US Global Climate Change Program, 2001). The warmer Canadian model scenario which anticipates increased drought stress, projects a 30 percent increase in fire severity for the Southeast. If extreme events such as wind storms, tornadoes, and floods further increase forest fuel levels with widespread downed trees, there is a potential for larger, more catastrophic fires that could impact many of the desired conditions for the Forest.

Outbreaks of insects, diseases, and non-native invasive species

Disturbances associated with climate change can have secondary impacts indirectly caused by weather-related extremes. Increased variation in temperature and moisture can cause stress and increase the susceptibility of forest ecosystems to invasions by insects, diseases, and non-native species. New environmental conditions can lead to a different mix of species and tend to be favorable to plants and animals that can adapt their biological functions or are aggressive in colonizing new territories (Whitlock, 2008). However, changes in adaptability may be too slow given the predicted rate of change. Species that are already broadly adapted may become more prevalent and species with narrow adaptability may become less prevalent. Disturbance factors that create more vulnerability in native ecosystems or require extensive controls to maintain the status quo are likely to affect desired conditions for healthy and diverse forests.

Desired conditions for healthy forests include resilience to dramatic changes caused by abiotic and biotic stressors and mortality agents (particularly the southern pine beetle) and a balanced supply of essential resources (light, moisture, nutrients, growing space). Insects and diseases typically invade in cycles followed by periods of relative inactivity. However, recent studies have shown that periods of attack for some insects, such as southern pine beetle, are becoming continuous (Whitlock, 2008). Non-native invasive species are expected to continue to increase in numbers and extent. Vulnerabilities to forest threats from an environment that may be much different from the historic range of natural variability is an active area of research right now and includes developing new management approaches for changing conditions.

Potential Climate Change Management Strategies

The potential management approaches described below relate to the principal climate change factors (extreme weather events, fire, and outbreaks of insects, diseases, and non-native invasive species) that are most likely to be a potential concern for the Uwharrie National Forest in moving toward the desired conditions in the Forest Plan. These strategies focus on ways to incorporate changes from disturbances into managed forests and enhance ecosystem resilience.

In developing strategies for managing future changes, the range of possible approaches could be quite broad, but the strategies which follow are focused on recommendations from recent research studies (including the U.S. Climate Change Science Program, SAP 4.4, June 2008, Final Report that includes a case study on the Uwharrie NF) that are appropriate for the North Carolina piedmont and balance effectiveness, feasibility, and available resources. Although some strategies are new ideas, most of these management options include practices that are already in effect, can serve multiple needs, and may just need to be adjusted or expanded to respond to climate changes during the next 15 years. Using an adaptive management approach will allow forest managers to adopt and adjust strategies as new information is available, conditions change, and staff and resources are available.

Climate Change Strategies for Uwharrie National Forest:

1. Reduce vulnerability by maintaining and restoring resilient native ecosystems.

In the Forest Plan, one of the basic elements of forest-wide desired conditions for ecosystem diversity is that native ecological systems occupy appropriate sites. Conversion of loblolly pine stands that are not on appropriate sites to better-adapted native species such as longleaf pine forests and oak-hickory stands are key restoration steps in this effort. In most parts of the South, loblolly pine historically grew along streams and moist sites where fire frequency was limited. Early reforestation efforts across the region after national forest establishment and subsequent fire suppression led to widespread plantings of loblolly on sites that were drier and more susceptible to fire. Restoration of longleaf pine which is better adapted to fire and dominated these drier sites before European settlement would not only be a step toward desired conditions but also a step toward reducing vulnerability to anticipated disturbances. Recent studies indicate that longleaf is less damaged from storms than loblolly, appears to have less insect and pathogen problems, has greater fire resistance, can grow as fast as or faster than loblolly pine after the grass stage, and as a result may sequester more carbon (Johnsen and Nelson, 2008). Based on native site conditions, longleaf pine would be expected to have higher resilience to a changing climate that is warmer, drier, and likely to have higher fire hazards. Future reforestation efforts could also take advantage of storm damage events to advance conversions of loblolly pine sites to longleaf pines. Restoration of other native ecosystems such as shortleaf pines, oaks, hickories, glades and barrens, and mafic hardpan woodlands would also move the forest toward desired conditions while enhancing resilience.

2. Emphasize management practices for coping with increased soil erosion.

With the projected increase in extreme weather events, best management practices for reducing soil erosion may be even more critical in the future. Standard soil erosion management practices such as buffers, filter strips, broad-based dips, and piling slash downslope of skid trails and along streams can help mitigate increased erosion conditions. Trails close to streams may need to be relocated further away from stream channels as part of improving and maintaining the recreation trails system and reducing impacts to water quality. Use of bridge mats and appropriately sized culverts at stream crossings should consider projections for future runoff in a changing climate as well as historic conditions.

3. Enhance adaptation by reducing the severity of disturbances and taking advantage of disruptions

Removal of trees susceptible to wind or ice storms and altered spacing or thinning of dense forest stands to reduce vulnerability to drought or windthrow are potential management options for improving resilience to more frequent and intense disturbance events. Vulnerability could be lessened by converting to species that are less susceptible to wind breakage and uprooting and to subsequent deterioration from insects and diseases. Maintaining wind buffers around high value resources like habitat for species-of-concern or species-of-interest would be an appropriate management tool.

Prescribed fires are a current management tool that can serve multiple purposes, from sustaining desired conditions for fire-dependent ecosystems and threatened and endangered species to reducing fuel loads. Prescribed burning is also a management strategy that will be important for maintaining desired habitats in a changing climate with more natural disturbances. With projections of more frequent storms and other more extreme weather events plus the potential for increased stresses from forest pests in a warmer, drier climate, continued prescribed burning will be an important management strategy for the future.

Although occurrences of storms and other disturbances cannot be precisely predicted, anticipatory planning can predict impacts and have guidelines in place to protect sensitive areas. Areas such as riparian zones, endangered species habitats, and special areas may require different approaches for reducing disturbances or recovering from damaging events. Management responses from previous events can provide guidance for similar situations and take advantage of prior learning experiences. Planning prior to disruptions can take advantage of disturbances when they eventually occur to convert vegetation to more resilient and desirable ecosystems and reduce assessment and response time while ensuring sensitive resources that require special responses are protected.

4. Use preventative measures to reduce opportunities for forest pests

Although current programs and guidance are already in place to limit introduction of non-native species, treat invasive species, and control insects and diseases, these efforts are likely to become more critical to maintaining desired conditions for healthy forests under a changing climate. Due to the fragmented land ownership patterns, success in reducing forest pests requires going beyond national forest boundaries, and continued work with partners will be needed. In addition, management practices (such as thinning and age class diversity) that sustain healthy forests and provide adequate nutrients, soil productivity, and hydrologic function promote resilience and reduce opportunities for disturbance and damage.

5. Reduce carbon loss from storm events

Salvaging and converting downed biomass into boards and other wood products can help reduce carbon loss after severe storms. Another consideration may be to use biomass that cannot be converted to wood products (such as from clearing roads and trails) for bioenergy production. Bioenergy production would be carbon neutral and could not only replace the use of fossil fuels in generators but mobile generation facilities could also return power to schools, hospitals, command centers, and other immediate needs long before power is generally available.

6. Monitor climate change influences

Climate change is a challenge to address in our monitoring program at the local national forest level because there are multiple influences that are not well understood and many of the indicators are observable only at a very broad level over extended periods of time. However, forest disturbance has been identified as an indicator that can be observed (Dale et al, 2001). Although direct cause-effect relationships of individual disturbance events may not always be evident, it should be possible to see changes over time and determine whether they may be related to climate change factors.

Monitoring

The following monitoring questions will address how well the Uwharrie National Forest is approaching its desired condition with regard to restoring native ecosystems and biodiversity:

1. What are the trends in restoring longleaf pine forests and oak-hickory forests?
2. What are the trends in NIS (non-native invasive species) plants?
3. What are the trends in ecological system conditions?
4. What are the trends in conditions for hydrologic stability, instream habitat, and streamside vegetation?

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