

ASSESSING THE POTENTIAL EFFECTS OF CLIMATE CHANGE ON UWHARRIE NATIONAL FOREST



Forestlands across the region are experiencing increased threats from fire, insect and plant invasions, disease, extreme weather, and drought. Scientists project increases in temperature and changes in rainfall patterns that can make these threats occur more often, with more intensity, and/or for longer durations. Although many of the effects of future changes are negative, natural resource management strategies can help mitigate these impacts. Responses informed by the best current science enable natural resource professionals within the Forest Service to better protect the land and resources and protect the region's forestlands into the future.

Forest Health - Invasive plant and insect species may increasingly outcompete or negatively affect native species in the future. Winter freezes historically limit the range of forest pests but higher temperature will likely allow increases in their number and spread. Drought and other factors will increase the susceptibility of forests to destructive insects such as the southern pine beetle. Certain invasive plant species, including kudzu and honeysuckle, are expected to increase dramatically as they can tolerate a wide range of harsh conditions, allowing them to rapidly move into new areas.

Response: Manage tree densities through practices such as thinning and prescribed fire to maximize carbon sequestration and reduce the vulnerability of forest stands to water stress, insect and disease outbreaks, and wildfire.

Response: Continually monitor for new invasive species moving into areas where they were not traditionally found, especially following events such as hurricanes and fire.

Plant Communities - Heat stress may limit the growth of some southern pines and hardwood species. Stress from drought and wide-scale pest outbreaks have the potential to cause large areas of forest dieback. Intensified extreme weather events, such as hurricanes, ice storms, and fire, are also expected to cause changes in plant community composition. Species of rare or endemic plants, including the endangered Schweinitz's Sunflower, may be particularly vulnerable to future changes. Species more resistant to these disturbances will be more resilient to a changing climate.

Response: Focus restoration efforts in hurricane-resistant forests, such as longleaf pine as well as sweetgum or red oak hardwood.

Response: Manage for a range of ages and species in forests to lessen potential loss from drought or infestation.

Animal Communities - Wildlife species will be affected in different ways. Amphibians may be most at risk as suitable habitat decreases due to warmer, dryer conditions. Bird species, such as the red-cockaded woodpecker, may see a decrease in population as vegetation types change and heat stress makes food sources more difficult to come by. Alternatively, deer populations may increase due to higher survival rates during warmer winters.



Forest disturbed by bark beetle



Schweinitz's Sunflower



Red-Cockaded Woodpecker

Response: Maintain piles of natural woody debris in areas of high amphibian diversity to supplement habitats that retain cool, moist conditions.

Response: Create habitat corridors, assist in species movement, and identify high-value conservation lands adjacent to National Forests.

Extreme Weather - The potential for severe storm events is expected to increase in the future, including more intense hurricanes making landfall in the southern US. Extended periods of extreme high temperature and drought may lead to drier forest fuels which will burn more easily and contribute to larger and more frequent wildfires. More cloud-to-ground lightning due to warming may also increase wildfire ignitions.

Response: Identify areas that provide particularly valuable ecosystem services, like timber harvest or carbon sequestration, and are also vulnerable to extreme weather, like hurricanes or fires. Then plan conservation strategies (e.g. thinning, selective species planting) accordingly to mitigate for extreme weather impacts.

Response: Reduce increased wildfire potential by conducting prescribed burns.

Water Resources - Shifts in rainfall patterns will lead to periods of flooding and drought that can significantly impact water resources. Increases in heavy downpours and more intense hurricanes can lead to greater erosion and more sedimentation in waterways. Increased periods of drought may lead to poor water quality. Geographically isolated wetlands are critical wildlife habitat and can be impacted by changes in surrounding landcover.

Response: Reduce the amount of water taken in by surrounding trees and plants, such as thinning and prescribed burns, in order to relieve stress on isolated wetlands and streams.

Response: Relieve groundwater and large reservoir use when there is ample surface water during wet periods or times of high water flow to recharge aquifers, provide temporary irrigation, and decrease stored sediment loss.

Response: Restore and reinforce vegetation in headwater and marsh areas to help alleviate runoff of sediment during heavy rain, reduce climate-induced warming of water, and decrease water sensitivity to changes in air temperature.

Recreation - Environmental changes may negatively impact recreational experiences due to changes in the plant and animal communities that make those experiences unique. More days above freezing could increase tick and mosquito populations throughout the year, leading to an increase in vector-borne illness. With more days of extreme heat, recreation areas could see decreased use in the summer if temperatures impact visitor comfort.

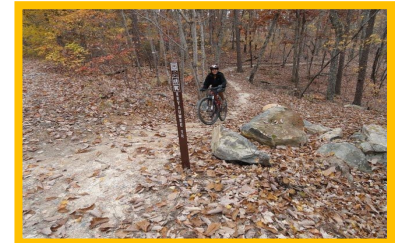
Response: Communicate early warnings for extreme weather to protect vulnerable groups from health impacts, such as heat illnesses, and monitor for early outbreaks of disease.



Mill Pond, Uwharrie



Storm in the Uwharrie



Mountain bikers

CLIMATE CHANGE AND YOUR NATIONAL FOREST: CITATIONS

Information in this factsheet is summarized from 56 peer-reviewed science papers found in the USDA Forest Service's TACCIMO tool. TACCIMO (the Template for Assessing Climate Change Impacts and Management Options) is a web-based application integrating climate change science with management and planning options through search and reporting tools that connect land managers with peer-reviewed information they can trust. For more information and the latest science about managing healthy forests for the future visit the TACCIMO tool online: www.forestthreats.org/taccimotool



Forest Health

- Coyle, D.R., Klepzig, K., Koch, F., Morris, L.A. Nowak, J.T., Oak, S.W., Otrosina, W.J., Smith, W.D., and Gandhi, K.J.K. (2015). A review of southern pine decline in North America. *Forest Ecology and Management*.
- Formby, J. P., Rodgers, J. C., Koch, F. H., Krishnan, N., Duerr, D. A., & Riggins, J. J. (2018). Cold tolerance and invasive potential of the redbay ambrosia beetle (*Xyleborus glabratus*) in the eastern United States. *Biological Invasions*, 20(4), 995-1007.
- Greenberg, C. H., Perry, R. W., Franzreb, K. E., Loeb, S. C., Saenz, D., Rudolph, D. C., & Tanner, G. W. (2013). Climate Change and Wildlife in the Southern United States. In: Vose, J. M., Klepzig, K. D., eds. *Climate change adaptation and mitigation management options: A guide for natural resource managers in southern forest ecosystems*. Boca Raton, FL: CRC Press. 379-420.
- Iverson, L. R., Prasad, A. M., Peters, M. P., & Matthews, S. N. (2019). Facilitating Adaptive Forest Management under Climate Change: A Spatially Specific Synthesis of 125 Species for Habitat Changes and Assisted Migration over the Eastern United States. *Forests*, 10(11), 989.
- Just, M. G., & Frank, S. D. (2020). Thermal Tolerance of Gloomy Scale (Hemiptera: Diaspididae) in the Eastern United States. *Environmental Entomology*.
- Kolb, T. E., Fettig, C. J., Ayres, M. P., Bentz, B. J., Hicke, J. A., Stewart, J.E. & Weed, A. S. (2016). Observed and anticipated impacts of drought on forest insects and diseases in the United States. *Forest Ecology and Management*, 380, 321 – 344. <http://dx.doi.org/10.1016/j.foreco.2016.04.051>
- McNulty, S., Baca, A., Bowker, M., Brantley, S., Dreaden, T., Golladay, S. W., Holmes, T., James, N., Liu, S., Lucardi, R. & Mayfeld, A. (2019). Managing Effects of Drought in the Southeast United States. In: Vose, James M.; Peterson, David L.; Luce, Charles H.; Patel-Weyand, Toral, eds. *Effects of drought on forests and rangelands in the United States: translating science into management responses*. Gen. Tech. Rep. WO-98. Washington, DC: US Department of Agriculture, Forest Service, Washington Office. 191-220. Chapter 9., 191-220.
- Miller, J. H., Lemke, D., Couston, J. The Invasion of Southern Forests by Nonnative Plants: Current and Future Occupation, with Impacts, Management Strategies, and Mitigation Approaches (2013) In, Wear, D. N., Greis, J. G., eds. *The Southern Forest Futures Project*. General Technical Report SRS-GTR-178. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.
- Minucci, J. M., Miniati, C. F., & Wurzbarger, N. (2019). Drought sensitivity of an N₂-fixing tree may slow temperate deciduous forest recovery from disturbance. *Ecology*.
- Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J. & Lexer, M. J. (2017). Forest disturbances under climate change. *Nature climate change*, 7(6), 395.

Plant Communities

- Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., ... & Cobb, N. (2010). A global

- overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management*, 259(4), 660-684. doi:10.1016/j.foreco.2009.09.001
- Clark, K. E., Chin, E., Peterson, M. N., Lackstrom, K., Dow, K., Foster, M., & Cabbage, F. (2018). Evaluating climate change planning for longleaf pine ecosystems in the Southeast United States. *Journal of the Southeast Association of Fish and Wildlife Agencies*, 5, 160-168.
- Conrad, A. O., Crocker, E. V., Li, X., Thomas, W. R., Ochuodho, T. O., Holmes, T. P., & Nelson, C. D. (2020). Threats to Oaks in the Eastern United States: Perceptions and Expectations of Experts. *Journal of Forestry*, 118(1), 14-27.
- Emanuel, R. E. (2018). Climate change in the Lumbee River watershed and potential impacts on the Lumbee tribe of North Carolina. *Journal of Contemporary Water Research & Education*, 163(1), 79-93.
- Guldin, J. M. (2019). Silvicultural options in forests of the southern United States under changing climatic conditions. *New forests*, 50(1), 71-87.
- McDonnell, T. C., Belyazid, S., Sullivan, T. J., Bell, M., Clark, C., Blett, T., Evans, T., Cass, W., Hyde, A. & Sverdrup, H. (2018). Vegetation dynamics associated with changes in atmospheric nitrogen deposition and climate in hardwood forests of Shenandoah and Great Smoky Mountains National Parks, USA.
- Osburn, C. L., Rudolph, J. C., Paerl, H. W., Hounshell, A. G., & Van Dam, B. R. (2019). Lingering carbon cycle effects of Hurricane Matthew in North Carolina's coastal waters. *Geophysical Research Letters*, 46(5), 2654-2661.
- Ryan, M., Archer, S., Birdsey, R., Dahm, C., Heath, L., Hicke, J., . Schlesinger, W. (2008). Land resources. in: *The effects of climate change on agriculture, land resources, water resources, and biodiversity. a report by the U.S. climate change science program and the subcommittee on global change research. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*, 362.
- Potter, K. M., Crane, B. S., & Hargrove, W. W. (2017). A United States national prioritization framework for tree species vulnerability to climate change. *New forests*, 48(2), 275-300.
- Walter, J. A., Neblett, J. C., Atkins, J. W., & Epstein, H. E. (2017). Regional-and watershed-scale analysis of red spruce habitat in the southeastern United States: implications for future restoration efforts. *Plant ecology*, 218(3), 305-316.

Animal Communities

- Blaustein, A. R., Walls, S. C., Bancroft, B. A., Lawler, J. J., Searle, C. L., & Gervasi, S. S. (2010). Direct and indirect effects of climate change on amphibian populations. *Diversity*, 2(2), 281- 313. doi:10.3390/d2020281
- DeMay, S. M., & Walters, J. R. (2019). Variable effects of a changing climate on lay dates and productivity across the range of the Red-cockaded Woodpecker. *The Condor*.
- Gade, M. R., & Peterman, W. E. (2019). Multiple environmental gradients influence the distribution and abundance of a key forest-health indicator species in the Southern Appalachian Mountains, USA. *Landscape Ecology*, 34(3), 569-582.
- Grant, E. H. C., Brand, A. B., DeWekker, S. F., Lee, T. R., & Wofford, J. E. (2018). Evidence that climate sets the lower elevation range limit in a high-elevation endemic salamander. *Ecology and evolution*,

8(15), 7553-7562.

- Joyce, L. A., Blate, G. M., Littell, J. S., McNulty, S. G., Millar, C. I., Moser, S. C., Peterson, D. L. (2008). National forests. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. a report by the U.S. climate change science program and the subcommittee on global change research. EPA, 1-127.
- Lawler, J. J. & Olden, J. D. (2011). Reframing the debate over assisted colonization. *Frontiers in Ecology and the Environment*, doi:10.1890/100106
- Mainwaring, M. C., Barber, I., Deeming, D. C., Pike, D. A., Roznik, E. A., & Hartley, I. R. (2017). Climate change and nesting behaviour in vertebrates: a review of the ecological threats and potential for adaptive responses. *Biological Reviews*, 92(4), 1991-2002.
- O'Keefe, J. M., & Loeb, S. C. (2017). Indiana bats roost in ephemeral, fire-dependent pine snags in the southern Appalachian Mountains, USA. *Forest Ecology and Management*, 391, 264-274.
- Taillie, P. J., Moorman, C. E., Smart, L. S., & Pacifici, K. (2019). Bird community shifts associated with saltwater exposure in coastal forests at the leading edge of rising sea level. *PLoS one*, 14(5), e0216540.

Extreme Weather

- Fill, J. M., Davis, C. N., & Crandall, R. M. (2019). Climate change lengthens southeastern USA lightning-ignited fire seasons. *Global change biology*.
- Flanagan, S. A., Bhotika, S., Hawley, C., Starr, G., Wiesner, S., Hiers, J. K., O'Brien, J.J., Goodrick, S., Callahan Jr, M.A., Scheller, R.M. & Klepzig, K. D. (2019). Quantifying carbon and species dynamics under different fire regimes in a southeastern US pineland. *Ecosphere*, 10(6), e02772.
- Hu, H., Wang, G. G., Bauerle, W. L., & Klos, R. J. (2017). Drought impact on forest regeneration in the Southeast USA. *Ecosphere*, 8(4), e01772.
- Jensen, A. M., Scanlon, T. M., & Riscassi, A. L. (2017). Emerging investigator series: the effect of wildfire on streamwater mercury and organic carbon in a forested watershed in the southeastern United States. *Environmental Science: Processes & Impacts*, 19(12), 1505-1517.
- Knutson, T. R., McBride, J. L., Chan, J., Emanuel, K., Holland, G., Landsea, C., Held, I., Kossin, J. P., Srivastava, A. K., & Sugi, M. (2010). Tropical cyclones and climate change. *Nature Geoscience*, 3(3), 157-163. doi:10.1038/ngeo779
- Mitchell, R. J., Liu, Y., O'Brien, J. J., Elliott, K. J., Starr, G., Miniati, C. F., & Hiers, J. K. (2014). Future climate and fire interactions in the southeastern region of the United States. *Forest Ecology and Management*, 327, 316-326.
- Osburn, C. L., Rudolph, J. C., Paerl, H. W., Hounshell, A. G., & Van Dam, B. R. (2019). Lingerin carbon cycle effects of Hurricane Matthew in North Carolina's coastal waters. *Geophysical Research Letters*, 46(5), 2654-2661.
- Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J. & Lexer, M. J. (2017). Forest disturbances under climate change. *Nature climate change*, 7(6), 395.
- Trenberth, K. E., Cheng, L., Jacobs, P., Zhang, Y., & Fasullo, J. (2018). Hurricane Harvey links to ocean heat content and climate change adaptation. *Earth's Future*, 6(5), 730-744.

Water Resources

- Bhattachan, A., Emanuel, R. E., Ardon, M., Bernhardt, E. S., Anderson, S. M., Stillwagon, M. G., Ury, E.A., Bendor, T.K. & Wright, J. P. (2018). Evaluating the effects of land-use change and future climate change on vulnerability of coastal landscapes to saltwater intrusion. *Elem Sci Anth*, 6(1).
- Erwin, K. L. (2009). Wetlands and global climate change: the role of wetland restoration in a changing world. *Wetlands Ecology and Management*, 17(1), 71-84. doi:10.1007/s11273-008-9111
- Hwang, T., Martin, K. L., Vose, J. M., Wear, D., Miles, B., Kim, Y., & Band, L. E. (2018). Nonstationary Hydrologic Behavior in Forested

Watersheds Is Mediated by Climate-Induced Changes in Growing Season Length and Subsequent Vegetation Growth. *Water Resources Research*, 54(8), 5359-5375.

- Karl, T. R., Melillo, J. M., & Peterson, T. C. (2009). *Global climate change impacts in the United States*. New York, NY, USA: Cambridge University Press.
- Liu, Y., Prestemon, J. P., Goodrick, S. L., Holmes, T. P., Stanturf, J. A., Vose, J. M., Sun, G. (2014) Future wildfire trends, impacts, and mitigation options in the Southern United States. In: Vose, J. M., Klepzig, K. D., eds. *Climate change adaptation and mitigation management options*. Boca Raton, FL: CRC Press. 85- 126.
- McDonnell, T. C., Sloat, M. R., Sullivan, T. J., Dolloff, C. A., Hessburg, P. F., Povak, N. A., ... & Sams, C. (2015). Downstream Warming and Headwater Acidity May Diminish Coldwater Habitat in Southern Appalachian Mountain Streams. *PLoS one*, 10 (8), e0134757.
- McNulty, S., Baca, A., Bowker, M., Brantley, S., Dreaden, T., Golladay, S. W., Holmes, T., James, N., Liu, S., Lucardi, R. & Mayfield, A. (2019). Managing Effects of Drought in the Southeast United States. In: Vose, James M.; Peterson, David L.; Luce, Charles H.; Patel-Weynand, Toral, eds. *Effects of drought on forests and rangelands in the United States: translating science into management responses*. Gen. Tech. Rep. WO-98. Washington, DC: US Department of Agriculture, Forest Service, Washington Office. 191-220. Chapter 9., 191-220.
- Osburn, C. L., Rudolph, J. C., Paerl, H. W., Hounshell, A. G., & Van Dam, B. R. (2019). Lingerin carbon cycle effects of Hurricane Matthew in North Carolina's coastal waters. *Geophysical Research Letters*, 46(5), 2654-2661.
- Susaeta, A., Adams, D. C., Gonzalez-Benecke, C., & Soto, J. R. (2017). Economic Feasibility of Managing Loblolly Pine Forests for Water Production under Climate Change in the Southeastern United States. *Forests*, 8(3), 83.
- Wisser, D., Froliking, S., Hagen, S. & Bierkens, M. F. P. (2013). Beyond peak reservoir storage? A global estimate of declining water storage capacity in large reservoirs. *Water Resources Research*, 49, 5732 – 5739. doi:10.1002/wrcr.20452.
- Zhu, J., Sun, G., Li, W., Zhang, Y., Miao, G., Noormets, A., McNulty, S.G., King, J.S., Kumar, M. & Wang, X. (2017). Modeling the potential impacts of climate change on the water table level of selected forested wetlands in the southeastern United States. *Hydrology and Earth System Sciences*, 21(12), 6289-6305

Recreation

- Boyer, T. A., Melstrom, R. T., & Sanders, L. D. (2017). Effects of climate variation and water levels on reservoir recreation. *Lake and reservoir management*, 33(3), 223-233.
- Joyce, L. A., Blate, G. M., Littell, J. S., McNulty, S. G., Millar, C. I., Moser, S. C., Peterson, D. L. (2008). National forests. in: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. a report by the U.S. climate change science program and the subcommittee on global change research. U.S. EPA, 1-127.
- Jurjonas, M., & Seekamp, E. (2018). Rural coastal community resilience: Assessing a framework in eastern North Carolina. *Ocean & coastal management*, 162, 137-150.
- Luber, G., K. Knowlton, J. Balbus, H. Frumkin, M. Hayden, J. Hess, M. McGeehin, N. Sheats, L. Backer, C. B. Beard, K. L. Ebi, E. Maibach, R. S. Ostfeld, C. Wiedinmyer, E. Zielinski-Gutiérrez, &
- L. Ziska, (2014). Ch. 9: Human Health. *Climate Change Impacts in the U.S.: Third NCA*. J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 220-256.
- Tully, K., Gedan, K., Epanchin-Niell, R., Strong, A., Bernhardt, E. S., Bendor, T., Mitchell, M., Kominoski, J., Jordan, T.E., Neubauer, S.C. & Weston, N. B. (2019). The Invisible Flood: The Chemistry, Ecology, and Social Implications of Coastal Saltwater Intrusion. *BioScience*, 69(5), 368-378.
- VanCompernelle, Michelle & Knouft, Jason & Ficklin, Darren. (2019). Multispecies conservation of freshwater fish assemblages in response to climate change in the southeastern United States. *Diversity and Distributions*.