ASSESSING THE POTENTIAL EFFECTS OF CLIMATE CHANGE ON CHATTAHOOCHEE AND OCONEE NATIONAL FORESTS

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, resources, and 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 found in these forests, including Japanese honeysuckle, are expected to increase dramatically as they are able to 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 such as the threatened large-flowered skullcap may be particularly vulnerable due to stress from Japanese honeysuckle. Species more resistant to these disturbances will be more resilient to a changing climate.

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. A changing climate may be harmful to the endangered gray bat by impacting their food supply and the internal temperature of their roosting caves. Bird species, such as red-cockaded woodpeckers, may see a decrease in population as vegetation types change and heat stress increases.

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

Picnic by the waterfall

Mountain bog

Large-flowered skullcap

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, using management strategies such as thinning and prescribed burns, in order 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.

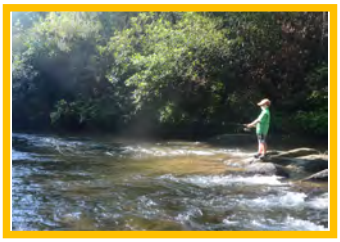
Response: Restore and reinforce vegetation in headwater and marsh areas to help alleviate runoff of sediment during heavy rain, reduce climate-induced warming of water, and decrease water sensitivity to changes in air temperature.

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.

Canoeing on Toccoa River

Fall forest colors



Fishing

Climate Change and Your National Forest: Citations

Information in this factsheet is summarized from 50 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.

Dijak, W. D., Hanberry, B. B., Fraser, J. S., He, H. S., Wang, W. J., & Thompson, F. R. (2017). Revision and application of the LINKAGES model to simulate forest growth in central hardwood landscapes in response to climate change. Landscape ecology, 32(7), 1365-1384.

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. 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-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.

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- Asheville, NC: U.S. Department of Agriculture, Forest Ser-vice, Southern Research Station.

Ryan, M., Archer, S., Birdsey, R., Dahm, C., Heath, L., Hicke, J. Schlesinger, W. (2008). Land resources. in: The effects of cli- mate 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.

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, 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., & Cubbage, 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.

Guldin, J. M. (2019). Silvicultural options in forests of the southern United States under changing climatic conditions. New forests, 50(1), 71-87.

Hansen, A. J., Neilson, R. P., Dale, V. H., Flather, C. H., Iverson, L. R., Currie, D. J., Bartlein, P. J. (2001). Global change in forests: Responses of species, communities, and biomes. Bio-Science, 51, 765-779.

Mech, A. M., Tobin, P. C., Teskey, R. O., Rhea, J. R., & Gandhi, K. J. (2018). Increases in summer temperatures decrease the survival of an invasive forest insect. Biological invasions, 20(2), 365-374.

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), 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.

Hoffacker, M. L., Cecala, K. K., Ennen, J. R., Mitchell, S. M., & Davenport, J. M. (2018). Interspecific interactions are conditional on temperature in an Appalachian stream salamander community. Oecologia, 188(2), 623-631.

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.

Payne, C., McKenzie, P., Stark, R. Millar, J., Andrews, L., Dean, T., Mulhern, D., (2009). Gray Bat (Myotis grisescens) 5-Year Review: Summary and Evaluation. USFWS Midwest Region: Columbia Missouri Ecological Services Field Office.

Shoo, L. P., Olson, D. H., McMenamin, S. K. Murray, K. A. Van Sluys, M., Herbert, S. M., Bishopm, P. J. Hero, J. –M. (2011). Engineering a future for amphibians under climate change. Journal of Applied Ecology, 48, 487-492. doi: 10.1111/j.1365-2664.2010.01942.x

Torti, V. M. & Dunn, P. O. (2005). Variable effects of climate change on six species of North American birds. Oecologia, 145, 486–495.

VanCompernolle, 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.

Extreme Weather

Carter, L., A. Terando, K. Dow, K. Hiers, K.E. Kunkel, A. Lascurain, D. Marcy, M. Osland, and P. Schramm, 2018: Southeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA. doi: 10.7930/NCA4.2018.CH19

Emanuel, K. (2017). Assessing the present and future probability of Hurricane Harvey's rainfall. Proceedings of the National Academy of Sciences, 114(48), 12681-12684.

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

Flanagan, S. A., Bhotika, S., Hawley, C., Starr, G., Wiesner, S., Hiers, J. K., O'Brien, J.J., Goodrick, S., Callaham 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.

Fill, J. M., Davis, C. N., & Crandall, R. M. (2019). Climate change lengthens southeastern USA lightning-ignited fire seasons. Global change biology.

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. 85-126.

Knutson, T. R., McBride, J. L., Chan, J., Emanuel, K., Holland,G., Landsea, C., Held, I., Kossin, J. P., Srivastava, K., & Sugi, M. (2010). Tropical cyclones and climate change. Nature Geoscience, 3(3), 157-163. doi:10.1038/ngeo779.

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.,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.

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-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.

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

Havens, K. E., Ji, G., Beaver, J. R., Fulton, R. S., & Teacher, C. E. (2019). Dynamics of cyanobacteria blooms are linked to the hydrology of shallow Florida lakes and provide insight into possible impacts of climate change. Hydrobiologia, 829(1), 43-59.

Karl, T. R., Melillo, J. M., & Peterson, T. C. (2009). Global cli-mate change impacts in the United States. New York, NY, USA: Cambridge University Press.

Kirwan, M. L., & Gedan, K. B. (2019). Sea-level driven land conversion and the formation of ghost forests. Nature Climate Change, 9(6), 450.

Pierfelice, K. N., Graeme Lockaby, B., Krauss, K. W., Conner, W. H., Noe, G. B., & Ricker, M. C. (2017). Salinity influences on aboveground and belowground net primary productivity in tidal wetlands. Journal of Hydrologic Engineering, 22(1), D5015002.

Rieman, B. E., Hessburg, P. F., Luce, C., & Dare, M. R. (2010). Wildfire and management of forests and native fishes: Conflict or opportunity for convergent solutions? BioScience, 60 (6), 468.

Seager, R., Tzanova, A., & Nakamura, J. (2009). Drought in the Southeastern United States: Causes, variability over the last millennium, and the potential for future hydroclimate change. American Meteorological Society, 22(19), 5021-5045.

Stahl, M., Widney, S., & Craft, C. (2018). Tidal freshwater forests: Sentinels for climate change. Ecological engineering, 116, 104-109.

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.

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

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. Environmental Protection Agency, 1-127.

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 United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 220-256.

Scott, D., McBoyle, G., & Schwartzentruber, M. (2004). Climate change and the distribution of climatic resources for tourism in North America. Climate Research, 105-117.

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.