ASSESSING THE POTENTIAL EFFECTS OF CLIMATE CHANGE ON NATIONAL FORESTS IN ALABAMA

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

Southern pine beetle outbreak

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 other plants, including the endangered Alabama leather flower, will be particularly vulnerable to drier conditions. 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.

Alabama leather flower

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. The endangered gopher tortoise will likely be severely affected by increasing drought conditions due to climate change. Bird species, such as red cockaded woodpeckers, may see a decrease in population as vegetation types change and heat stress makes food more difficult to come by.

Gopher tortoise

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.

Stairway to Heaven-Pinhoti Trail-Cheaha Wilderness

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.

Prescribed burn in Montgomery, AL

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.

Payne Lake Recreation Area

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.

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 discomfort.

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

Climate Change and Your National Forest: Citations

Information in this factsheet is summarized from 58 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

Chen, X. (2019). Dynamics of forest composition and growth in Alabama of USA under human activities and climate fluctuation. Journal of sustainable forestry, 38(1), 54-67.

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.

Duehl, A. J., Koch, F. H., & Hain, F. P. (2011). Southern pine beetle regional outbreaks modeled on landscape, climate and infestation history. Forest Ecology and Management, 261(3), 473-479. doi:10.1016/j.foreco.2010.10.032

Duerr, D. A., Mistretta, P. A. Invasive Pests – Insects and Diseases (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

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.

Galik, C. S. & Jackson, R. B. (2009). Risks to forest carbon offset projects in a changing climate. Forest Ecology and Manage- ment, 257(11), 2209-2216. doi:10.1016/j.foreco.2009.03.017

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-178. Ashe- ville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Morrison, L. W., Korzukhin, M. D., & Porter, S. D. (2005). Predicted range expansion of the invasive fire ant, Solenopsis invicta, in the eastern United States based on the VEMAP global warming scenario. Diversity and Distributions, 11(3), 199-204. doi:10.1111/j.1366-9516.2005.00142.x

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 over- view of drought and heat-induced tree mortality reveals emerg- ing climate change risks for forests. Forest Ecology and Man- agement, 259(4), 660-684. doi:10.1016/j.foreco.2009.09.001

Bernazzani, P., Bradley, B., and Opperman, J. (2012). Integrating climate change into habitat conservation plans under the U.S. Endangered Species Act. Environmental Management, 49(6), 1103-1114. doi:10.1007/s00267-012-9853-2.

Bragg, D. C., Shelton, M. G., & Zeide, B. (2003). Impacts and forest management implications of ice storms in forests in the southern United States. Forest Ecology and Management, 186, 99-123.

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.

Davenport, L.J. (2007). Climate change and its potential effects on Alabama's plant life. Vulcan Materials Center for Environmental Stewardship and Education. http://www.samford.edu/images/Davenport_CLIMATECHANGE2007.pdf

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

Johnsen, K. H., Butnor, J. R., Kush, J. S., Schmidtling, R. C., & Nelson, C. D. (2009). Hurricane Katrina winds damaged long- leaf pine less than loblolly pine. Southern Journal of Applied Forestry, 33(4), 178-181.

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), 281- 313. doi:10.3390/d2020281s10021–001–0005-4

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.
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.
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.
McCoy, ED, Moore, RD., Mushinsky, H.R., Popa, S.C. (2011). Effects of Rainfall and the Potential Influence of Climate Change on Two Congeneric Tortoise Species
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.
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
Delphin, S., Escobedo, F. J., Abd-Elrahman, A., & Cropper Jr, W. (2013). Mapping potential carbon and timber losses from hurri- canes using a decision tree and ecosystem services driver mod- el. Journal of Environmental Management, 129, 599-607.
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.
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.
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.
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: 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, A. K., & Sugi, M. (2010). Tropical cyclones and climate change. Nature Geosci- ence, 3(3), 157-163. doi:10.1038/ngeo779
Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C.M., Kanae, S., Kossin, J., … & Zhang, X. (2012). Changes in climate extremes and their impacts on the natural physical environment. In: Field, C.B et al. (Eds.), Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge, UK, and New York, NY, USA: Cambridge University Press, 109- 230.
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

Acharya, A. (2017). Quantification of modeled streamflows under climate change over the flint river watershed in Northern Alabama. Journal of Hydrologic Engineering, 22(9), 04017032.
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/s11273-008-9119-1
Karl, T. R., Melillo, J. M., & Peterson, T. C. (2009). Global climate change impacts in the United States. New York, NY, USA: Cam-bridge University Press.
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), 460-468.
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.
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

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 eco- systems and resources. a report by the U.S. climate change science program and the subcommittee on global change re- search. 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 Im- pacts in the United States: The Third National Climate Assess- ment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 220-256.
Richardson, R. B., Loomis, J. B. (2004). Adaptive recreation plan- ning and climate change: a contingent visitation approach. Ecological Economics, 50, 83-99. doi:10.1016/ j.ecolecon.2004.02.010
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.