ASSESSING THE POTENTIAL EFFECTS OF CLIMATE CHANGE ON OZARK-ST. FRANCIS 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 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: Continually monitor for new invasive species moving into areas where they were not traditionally found, especially following events such as ice storms and fire.

Southern pine beetle outbreak

Indiana bat

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 tornados, ice storms, and fire, are also expected to cause changes in plant community composition. Some species of rare or endemic plants may be disproportionately impacted. Species more resistant to these disturbances will be more resilient to a changing climate.

Response: Replace fescue with native warm season grasses because they are more drought tolerant.
Response: Focus restoration efforts in storm-resistant forests, such as shortleaf 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.

Hellbender

Animal Communities - Wildlife species will be affected in different ways. Amphibians such as salamanders may be most at risk, as suitable habitat decreases due to warmer, dryer conditions. The Ozark hellbender is one such amphibian seeing a rapid decline in population and may be particularly affected. Greater ambient temperatures may be harmful to mammals such as the endangered Indiana bat.

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. 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 storms 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.

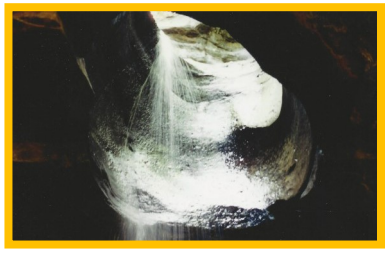
Response: Reduce the amount of water taken in by surrounding trees and plants, using management strategies such as thinning and prescribed burns, in order relieve stress on isolated wetlands and streams.
Response: Relieve groundwater and large reservoir use when there is ample surface water during wet 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 riparian 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 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.

Kudzu

Upper Buffalo



Glory Hole Waterfall

Climate Change and Your National Forest: Citations

Information in this factsheet is summarized from 55 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.

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. Ashe- ville, 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.

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-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 For- ests 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.

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

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.

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.

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.

Funk, J. L., Cleland, E. E., Suding, K. N., & Zavaleta, E. S. (2008). Restoration through reassembly: plant traits and invasion re- sistance. Trends in Ecology & Evolution, 23(12), 695-703. doi:10.1016/j.tree.2008.07.013

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

Hellmann, J. J., Byers, J. E., Bierwagen, B. G., & Dukes, J. S. (2008). Five potential consequences of climate change for invasive species. Conservation Biology, 22(3), 534-543.

Olatinwo, R., Guo, Q., Fei, S., Otrosina, W., Klepzig, K. D., Streett, D. (2014) Climate-Induced Changes in Vulnerability to Biologi- cal Threats 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. 127-172.

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., De Wekker, 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. in: Pre- liminary 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 Environ- ment, 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.
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.
Wells, C., & Tonkyn, D. (2018). Changes in the geographic distribution of the Diana fritillary (Speyeria diana: Nymphalidae) under forecasted predictions of climate change. Insects, 9(3), 94.
USFS. (2010) George Washington National Forest Revised Land and Resource Management Plan http://www.fs.usda.gov/ Internet/FSE_DOCUMENTS/stelprd3822820.pdf
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.
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.
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/ngeo77
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.
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.
Van Der Wiel, K., Kapnick, S. B., Van Oldenborgh, G. J., Whan, K., Philip, S., Vecchi, G. A., Singh, R.K., Arrighi, J. & Cullen, H. (2017). Rapid attribution of the August 2016 flood-inducing extreme precipitation in south Louisiana to climate change. Hydrol. Earth Syst. Sci, 21(2), 897-921.

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
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: Cam- bridge University Press.
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.
Wisser, D., Frolking, 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 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.
McDonnell, T. C., Sloat, M. R., Sullivan, T. J., Dolloff, C. A., Hess- burg, P. F., Povak, N. A., ... & Sams, C. (2015). Downstream Warming and Headwater Acidity May Diminish Coldwater Habi- tat in Southern Appalachian Mountain Streams. PloS one, 10 (8), e0134757.
Richardson, R. B., Loomis, J. B. (2004). Adaptive recreation planning and climate change: a contingent visitation approach. Ecological Economics, 50, 83-99. doi:10.1016/ j.ecolecon.2004.02.010
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