Issue of Concern: Drought

An increase in the frequency and severity of drought within Northeastern forests is expected over the next century due to climate change. The implications of this increase in drought conditions for forest ecosystems are complex and dependent on site-level characteristics. Moisture stress can hinder regeneration and alter the composition of a forest by impeding germination and establishment, and contributing to tree mortality. Stress created by drought conditions also increases the vulnerability of a forest to secondary impacts such as insect and disease outbreaks, and increased wildfire risk. Evidence supports that a variety of forest adaptation practices may prevent or ameliorate the negative effects of increasingly frequent and severe drought.

Climate Change Impacts

As rates of evapotranspiration increase with rising temperatures, moisture stress and drought conditions will occur more frequently if they are not offset by a corresponding increase in precipitation and soil moisture (Hayhoe et al. 2007, Kunkel et al. 2013). Modeling results suggest a much greater potential for more frequent droughts and moisture stress during the growing season when climate models project both much warmer temperatures and reduced summer precipitation in the Northeast. Even when precipitation is not projected to change substantially, warmer temperatures are also predicted to contribute to increased evapotranspiration and physiological stress if increases in precipitation do not correspond to temperature increases (Janowiak et al. 2018, Lynch et an 2016; Peters and Iverson 2019).

Moisture stress can negatively impact forest ecosystems in a variety of ways, and the potential effects will depend on many factors, including the duration and severity of the drought and site-level characteristics of the forest. Prolonged and/or severe drought conditions may contribute to tree dieback and mortality, particularly as these conditions interact with other forest stressors (Clark et al. 2019). Although mature trees are better able to resist increases in temperature and reductions in available moisture, severe or sustained drought can increase tree mortality, open the forest canopy, alter forest growth and composition, and increase susceptibility to other stressors (Clark et al. 2016, Dale et al. 2001, Millers et al. 1989, Pederson et al. 2014). Drought during the past century has been linked to dieback in sugar maple and some species of birch (Auclair et al. 2010), as well as a decline of oak and ash trees in the Northeast (Millers et al. 1989, Mohan et al. 2009).

Interactions between drought and other disturbances increase the likelihood of tree dieback and mortality (Coble et al. 2017). While purely drought induced mortality events are rather rare in the Northeast, moisture stressed trees are more vulnerable to disturbances, particularly insect pests and diseases (Dale et al. 2001, Millar and Stephenson 2015, Ryan and Vose 2012). Additionally, drought conditions can hinder forest recruitment and regeneration. Germination, establishment, and early seedling survival depend on early-season moisture, and can be limited by drought. When moisture is limited over successive years, the fecundity of adult trees may also be significantly reduced, as greater seed production is correlated with high levels of soil moisture (Clark et al. 2019).

Within oak forests, the dominant species are considered to be relatively drought tolerant and may potentially benefit from or at least endure future drought conditions. However, there are complexities that imply these forests may still be vulnerable. The ability of oak forests to cope with drought conditions may be hindered as species composition shifts toward more drought-intolerant species such as beech and maple. Impacts will be species-specific and are likely to vary based on the timing of drought within the growing season;

for instance, recent research indicates that *Quercus alba* may be particularly sensitive to low water availability early in the growing season (Fung Au et al. 2020).

There are still some uncertainties regarding the potential future impact of drought on forests in the Northeast. Approaches to drought risk assessment are variable and in many cases lack future scenario modelling. Additionally, there is a lack of agreement on drought risk assessment methods (Hagenlocher et al. 2019).

In the eastern US, the effects of increasing drought are becoming better understood at the level of individual trees, but this knowledge cannot yet be confidently translated to predictions of changing structure and diversity of forest stands (Clark et al. 2016).

Adaptation Actions for Forests

Additional actions are described in Adaptation Strategies and Approaches for Forests.

Site Condition	Adaptation Approaches	Example Adaptation Actions
Presence of drought prone soils	• Reduce competition for moisture, nutrients, and light • Maintain or restore hydrology • Favor or restore native species that are expected to be adapted to future conditions	• Thin to improve moisture availability for residual trees • Install berms or dikes to divert surface water to an area affected by decreased precipitation • Favor or establish oak, pine, and other more drought- and heat-tolerant species on narrow ridge tops, south-facing slopes with shallow soils, or other sites that are expected to become warmer and drier
Tree species present are more vulnerable to drought	• Restore or maintain fire in fire-adapted ecosystems	• Promote species that are tolerant of drought conditions • Use prescribed burning to promote fire and drought adapted species
High levels of tree mortality on a drought-prone site	• Favor existing genotypes that are better adapted to future conditions • Introduce species that are expected to be adapted to future conditions	• Plant stock from seeds collected from local trees that exhibit drought tolerance • Plant oaks, pines, and other drought-tolerant species on sites within the current range that are expected to become drier and that

		have not been historically occupied by those species

On-the-Ground Examples

- Massachusetts Department of Conservation & Recreation: Bristol Lot Timber Sale
  - Drought conditions have limited the effectiveness of a soil borne fungus that controls *Lymantria dispar*, making this oak-dominated stand highly susceptible to further heavy defoliation and mortality. In addition to planting blight-resistant American chestnut, managers are encouraging a mix of species, age classes, and stand structures to reduce the availability of host species for pests and pathogens.
- Florence County: Climate-informed Forest Restoration
  - A combination of drought and forest pests have resulted in a 90% mortality rate of trees within this 400 acre area. Managers are identifying healthy pockets of scrub oak and northern red oak to preserve, and planting jack pine, red pine, bur oak, and juneberry, as well as white pine and swamp white oak in riparian areas.

Potential Monitoring Items

- Record and report various drought conditions and impacts via the National Drought Mitigation Center's Drought Condition Monitoring Observation and Reports impact reporter.
- Learn how to assess local precipitation conditions and report them via the Community Collaborative Rain, Hail & Snow Network's (CoCoRaHS) reporting system and map.

Additional Resources

- Access drought forecast and severity ratings via the United States Drought.gov - Northeast webpage.
- Access a variety of drought and precipitation indices via the Northeast Drought Early Warning System webportal.
- Access past drought reports, a drought impact map, and official drought plans for each state through the National Drought Mitigation Center.