10. Climate Change

Since the mid- 20th century, scientists have recorded an unprecedented warming of temperatures across the earth. The scientific consensus is that the cause is due to human influences, also known as the anthropogenic climate change. (IPCC 2013, John et al. 2016) The largest human influence on rising temperatures, since the mid 1900's, has been the increase of greenhouse gases such as carbon dioxide (CO2), methane and nitrous oxide in the earth's atmosphere. Within the Northeast, temperatures increased by approximately 2.4 ^{o}F (1.3 ^{o}C) between 1901 and 2011 (Janowiak et al. 2017). In New Hampshire, average annual temperatures have increased 3 ^{o}F with the greatest warming occurring during the winter with an increase of about 4 ^{o}F since 1900 (www.statesummaries.ncics.org/nh). These warming trends have resulted in warmer winter nights, days with temperatures below freezing reduced by two weeks, and a lengthening of the growing season by twelve to forty-two days since 1960 in northern New Hampshire and by fifteen to fifty-two days in southern New Hampshire (Wake et al. 2014). In addition, the growing season is predicted to be extended by 3-7 weeks in northern New Hampshire and by 2-5 weeks by the year 2100 depending on the emission's scenario (Wake et al. 2014). (Kunkel et al. 2013, Ning et al. 2015). A longer growing season means a shorter frost-free period with less snowfall and shorter duration of snowpack. Milder winters have led to a decrease in the amount of precipitation falling as snow and the duration of snowpack (Campbell et al. 2010). With less snowpack, there is an increased risk of soil frost and root damage during the winter from less insulation from the snow (Groffman et al. 2012). Increased summer temperatures and more variable summer precipitation increase the risk of stress on riparian and floodplain vegetation due to lower summer flows. Figure 25 shows the New Hampshire and national average temperature trends.

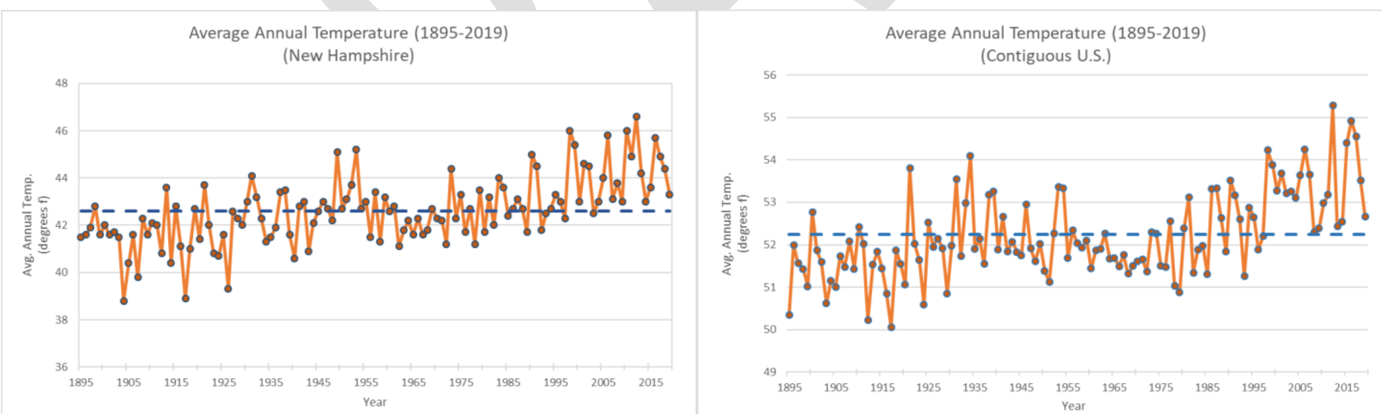

Figure 25 Trend in average annual temperature for NH and the US
Source: National Centers for Environmental Information, National Oceanic and Atmospheric Administration (NOAA)

Climate change is also a contributing factor in changing annual precipitation rates. In southern New Hampshire there was an increase in mean annual precipitation of 4.5 inches from 1895 – 2009 (Wake et al. 2014). The observed changes in northern New Hampshire include an increase in mean annual precipitation of 6.9 inches (+16 %) from 1901 to 2011 (Janowiak et al. 2017). Statewide average annual precipitation of 49 inches in the period 2010 to 2014 was second only to the record-setting average of 56 inches in 2005 – 2009. Additionally, the timing of when precipitation falls has shifted, with the greatest increase in precipitation observed in the fall (+3.0 inches) and the smallest increase in winter (+0.6 inches) (Janowiak et al. 2017). Perhaps the greatest impact in New England of a changing climate is the occurrence of extreme precipitation events (Speirre and Wake 2010, Wake et al. 2014). The amount of precipitation falling in very heavy events (heaviest 1% of all daily events) across the Northeast increased 71% between 1958 and 2012, more than any other region in the country (Melillo et al. 2014). Although it is not possible to attribute a single extreme weather event to having been caused by climate change, climate change does increase the likelihood for these events to occur (Kunkel et al. 2012). For example, there has been a strong increase in the intensity, frequency, and duration of hurricanes, especially the frequency of the strongest hurricanes (Category 4 and 5), in the North Atlantic since the 1970s due to warming sea surface temperatures (Walsh et al. 2014). Figure 26 shows New Hampshire and US annual precipitation trends.

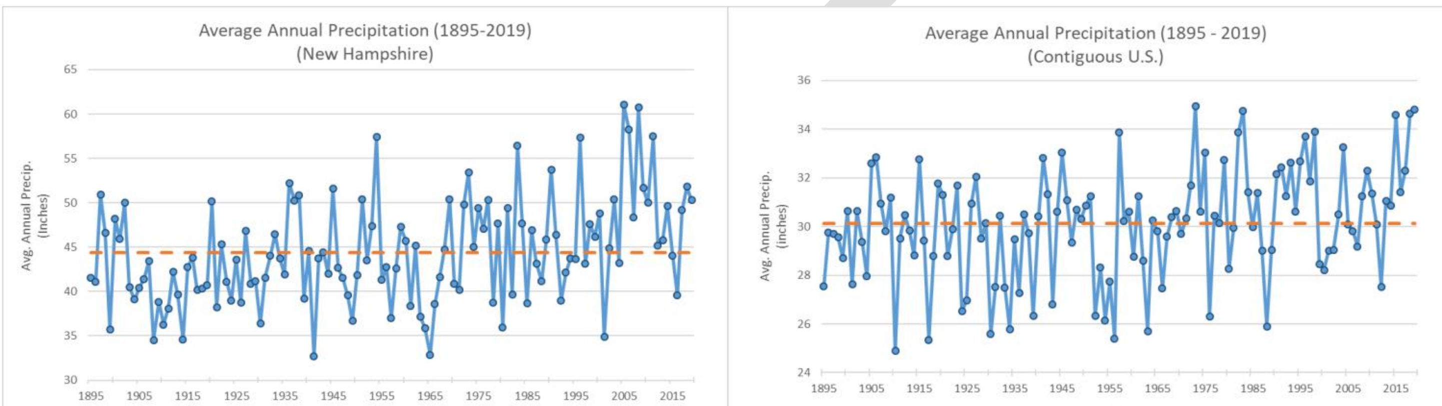

Figure 26 Trend in average annual precipitation for NH and the US
Source: National Centers for Environmental Information, National Oceanic and Atmospheric Administration (NOAA)

Impact on Trees

According to the Fourth National Climate Assessment, forests are already responding to the ongoing shift to a warmer climate, and changes in the timing of leaf-out affect plant productivity, plant–animal interactions, and other essential ecosystem processes (USGCRP, 2018). Warmer late-winter and early-spring temperatures in the Northeast have resulted in trends towards earlier leaf-out and blooming. Seasonal differences in Northeast temperature have decreased in recent years as winters have warmed three times faster than summers. The structure of forests, including the abundance of different tree species and the distribution of different ages of trees, is expected to change in response to climate change, but the degree and how it will change may differ amongst forest types (Janowiak et al. 2017, Manomet and NWF 2012, NHFG 2013). It is likely that our species-based definitions of natural communities may change, as individual plants react differently to increases in temperature and changes in the hydrological regime (NHFG 2013). Models of tree species abundance have been developed to provide insights into how tree species may respond into the future under low-emissions and high-emissions scenarios (Janowiak et al. 2017). For example, the Climate Change Tree Atlas (www.fs.fed.us/nrs/atlas) models future suitable habitat in the Northeast for 2100 and suggests that individual tree species will respond differently over time as the temperature warms. This model projects future suitable habitat of tree species, and suggests that spruce and fir will decline across the region, as will most of the northern conifer species (Janowiak et al. 2017). However, red maple, black cherry and red oak are expected to fare well with a changing climate. Sugar maple and yellow birch, are expected to decrease in the high emissions scenario, while under the low emissions scenario little change is expected in habitat suitability across the landscape. Sugar maple is a species that has fairly specific soil requirements, it does well on good quality soils; a species like this may not be able to shift its range within the region with greater warming expected under the high emissions scenario due to soil limitations. Table 8 shows future projections of New Hampshire's 20 most common tree species by volume under low and high climate change scenarios (USDA Forest Service Climate Change Atlas).

Forest Management

Warmer temperatures, Increased extreme weather events, and greater likelihood that precipitation will fall as rain in winter, may negatively impact timber harvesting operations and cause a decrease in harvest productivity. Areas that require timber harvesting to be done under frozen ground conditions may experience fewer days of operation in the winter. If there are fewer days with optimal conditions for timber harvesting due to a changing climate, substantial acreage may become effectively inaccessible without suitable ground conditions. This scenario effectively shrinks the total availability of timberland for management. Increased precipitation and extreme weather events will likely increase the costs for road development and maintenance to mitigate water quality impacts. The damage to trees from extreme events such as severe drought and high wind instigate insect outbreaks and wildfires which, in turn, may result in increased salvage harvesting.

Table 8 Projections for future suitable habitat – Climate Change Atlas

Species	**Northern Forest Region**		**Southern & Coastal NE**	
	LOW CLIMATE CHANGE	HIGH CLIMATE CHANGE	LOW CLIMATE CHANGE	HIGH CLIMATE CHANGE
Eastern white pine	●	●	▼	▼
Red maple	●	●	●	▼
Northern red oak	▲	▲	●	▼
Eastern hemlock	●	●	●	▼
Sugar maple	●	▼	●	●
Yellow birch	●	▼	●	▼
Red spruce	▼	▼	▼	▼
Balsam fir	▼	▼	▼	▼
American beech	●	▼	●	●
Paper birch	▼	▼	▼	▼
White Ash	●	●	●	●

Sweet birch	▲	▲	▲	▼
Quaking Aspen	●	▼	▼	▼
White oak	▲	▲	▲	▲
Black oak	▲	▲	▲	▲
Bigtooth aspen	●	●	●	▼
Black cherry	●	▲	●	●
Red pine	●	▲	●	▼
White spruce	▼	▼	▼	▼
American basswood	●	▲	●	▲

▲ INCREASE

Projected increase of > 20% by 2100

● NO CHANGE

Little change (<20%) by 2100

▼ DECREASE

Projected decrease of >20% by 2100

Water Resources

Major river and stream flooding events are generally expected to increase in frequency and intensity in the Northeast as a result of the increases in heavy precipitation events (Demaria et al. 2016). These kinds of events have a dramatic impact on streams. Flooding can either add or remove substrate from a section of river, and in the process alter habitat for fish, mussels, or macroinvertebrates. Damage to roads, culverts, and other infrastructure can cause sedimentation or otherwise impair waterways.

Beyond extreme rainfall, other changes in climate are expected to affect hydrology, water quality, and aquatic habitats. Warmer air temperatures and longer growing seasons can increase water temperatures, making water bodies less suitable for trout and other coldwater species, even in the absence of increased hydrological variability. (Staudinger et al. 2015, Williams et al. 2015). Base flows in the region's streams may be reduced and low base flows may occur more frequently as a result of earlier peak flows, more variable summertime precipitation, and increased frequency of abnormally hot weather (Walsh et al. 2014, Demaria et al 2016). However, streams with adequate sources of groundwater are generally more resistant to climate change (Chu et al. 2008). Populations of fish or other aquatic organisms that are already isolated as a result of river fragmentation may be particularly susceptible to additional stresses resulting from climate change. In such cases, fragmentation reduces the ability for species to recolonize an area where they have been extirpated (NHFG 2013).

Wildlife

Wildlife will respond in several ways to habitat changes that occur as a result of climate change. The gradual shift in the vegetative species composition will correspondingly create changes in habitat types and distribution. These changes in habitat may have less of an impact to some species while others will feel these effects more profoundly. Species that are more mobile may have a greater ability to shift into habitats that have experienced less change and remain more suitable. Species which can only move short distances may experience accelerated declines or disappear locally in the event that habitat conditions change considerably over time. For example, the predicted decline in northern conifer species has the potential to diminish the habitat availability for wildlife which depends on evergreen tree species for their habitat needs (NHFG 2014). As a result, locations on the Forest which continue to be favorable to the growth of softwood as the climate changes (known as refugia) may have increased importance for wildlife habitat over time as the abundance of evergreen species declines.

Warming temperatures and a corresponding decrease in the extent and duration of snowpack will likely also influence wildlife distribution. Mammals adapted to snow including snowshoe hare may shift to habitats at higher elevations where snow is more certain. Additionally, changes to vegetation composition over time resulting from a changing climate may influence the growth of nut and berry (mast) producing species, impacting the type and amount of food resources available to wildlife. Impacts on the synchronicity, abundance and vigor of mast cycles may impact the fitness of individual animals and wildlife population productivity over time.

Forest Health

Climate change is expected to increase many threats to forest health, including insect pests, diseases and invasive plants. Directly, some invasive plant species are disproportionality able to take advantage of an increased CO2 environment, and many insect pests and invasive plant species may be able to expand their ranges northward in response to warmer temperatures (Ramsfield et al. 2016, Ziska et al. 2009). Some insect pests and invasive plants have so far been prevented from establishing or increasing in population in northern NH due to the cold winters, and warming temperatures decrease the probability of cold lethal temperatures. For example, mortality of hemlock woolly adelgid is dependent on cold temperatures during winter as well as the timing of cold snaps. Warming trends will limit the probability of occurrence of cold lethal temperatures in NH and we may see northward migration of this and other insect species. Additionally, there is the potential for an accelerated life cycle of certain insect pests, allowing them to propagate more often and increase their populations rapidly with longer growing seasons (Ramsfield et al. 2016). Alternatively, tree pests such as spruce budworm are on the southern end of their range, and warming trends may limit the survival of this insect in NH in the future (Régnière et al. 2012). However, overall warming temperatures will make our trees more susceptible to insects and diseases over time, as all of these forms of stress continue to increase.

Recreation

Recreational activities are already seeing some impacts due to climate change, largely due to direct effects of temperature shifts and changes to precipitation patterns and severity. There is the possibility that these effects may increase and have more significant impacts on recreational use in the future. Less distinct seasons with milder winter and earlier spring conditions are already altering ecosystems and environments in ways that adversely impact tourism, farming, and forestry. The region's rural industries and livelihoods are at risk from further changes to forests, wildlife, snowpack, and streamflow (USGCRP, 2018).

Trails utilized by all types of user groups are at high risk from both temperature and precipitation extremes. Unusually dry periods have the effect of destabilizing soils by causing overly dry surfaces and sub-surfaces, thus making them more susceptible to erosion by heavy precipitation or mechanical disturbances. Conversely, periods of heavy rainfall or extended periods can have the effect of making trails that were traditionally used, no longer viable due to overly wet trail surfaces that cannot be easily crossed without an investment in reconstruction and constant maintenance. There will be an increase in costs associated with continuing to maintain proper trail management.

19. Urban and Community Forests

Urban and community forests are the trees, plants and associated ecosystems anywhere where people are. They include trees in public parks, town commons, community forests and trees along New Hampshire's roads and highways. Like electricity and water, an urban tree canopy is part of a community's infrastructure. New Hampshire's urban forests provide a wide range of ecological, economic and social benefits for the nearly 800,000 residents, 60 percent of the state's population, who live in urban areas (U.S. Census Bureau, 2012).

Although New Hampshire remains a predominantly rural state, it is becoming more urbanized. According to **"**US Urban Forest Statistics, Values, and Projections" (Nowak et al., 2018), New Hampshire's urban land increased from 6.1% in 2000 to 7.2% in 2010, and is projected to increase to 10.5 % by 2060 (Figure 65). In addition, while New Hampshire remains in the top five for percent of urban tree cover, the percent of urban tree cover decreased from 57.4% in 2009 to 56.3% in 2015 (Figure 66).

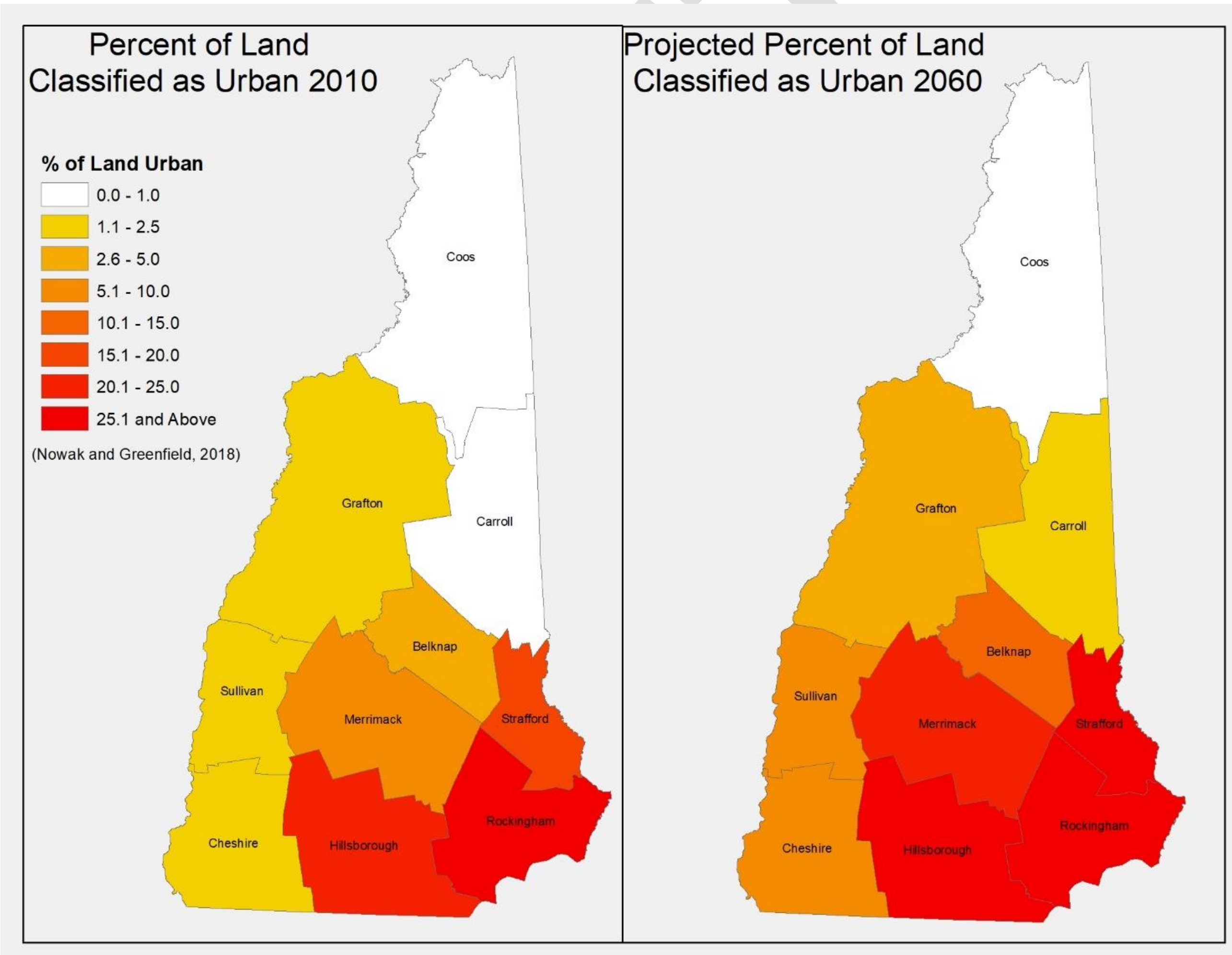

Figure 65 Percent of land classified as urban in 2010 and projected percent of land classified as urban in 2060.
Source: "US Urban Forest Statistics, Values, and Projections" (Nowak et al., 2018)

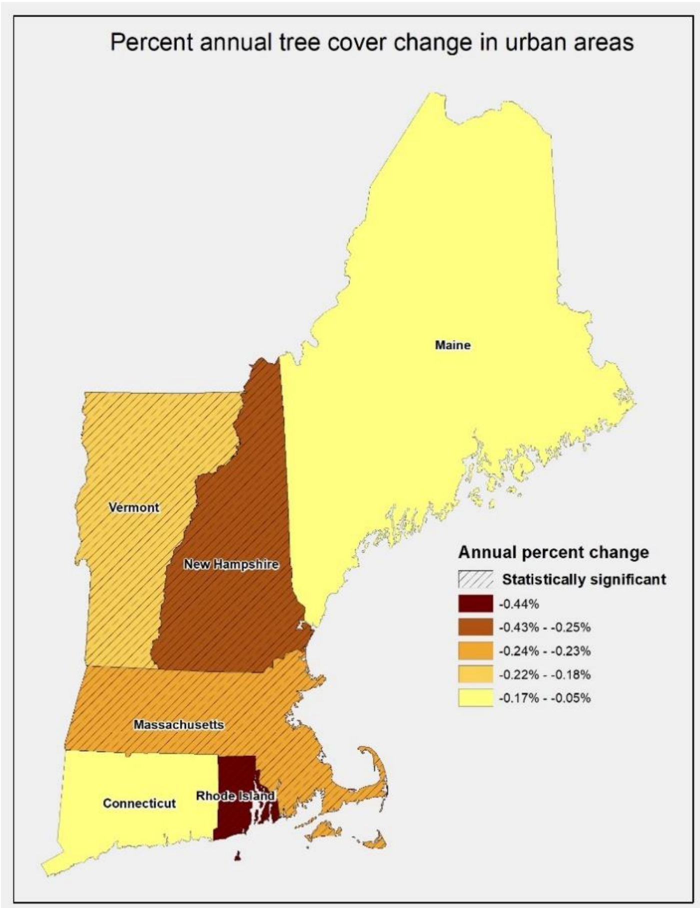

Figure 66 Annual percent tree cover change in urban areas
Source: "Declining urban and community tree cover in the United States" David J. Nowak, Eric J. Greenfield 2017

Urban and community trees and forests provide a variety of ecological and economical values including storm water management, reduced energy use, noise abatement, improved air quality, and atmospheric carbon sequestration. Through shading and cooling trees can reduce urban heat islands in the face of warming temperatures. New Hampshire's urban forests are estimated to remove about 5,700 tons of air pollutants a year, to the health benefit of over $15 million. The value of avoided energy use is estimated to be over $14.5 million per year and the amount of CO2 sequestered by urban trees in New Hampshire is estimated to be more than 244,000 tons per year (Nowak et al.; 2018).

State Urban Forestry programs receive funding through the USDA Forest Service State and Private Forestry Urban and Community Forestry program. In compliance with reporting requirements, New Hampshire Division of Forests and Lands (DFL) annually tracks local urban forestry program development for 234 communities through the Community Assistance Reporting System (CARS). These data show trends in the capacity of communities to manage their urban forests and can reveal both successes and opportunities for continued improvement. In 2019 DFL reported that there are 68 managing communities and 95 developing communities in New Hampshire (Figure 67). Managing communities must have an urban tree management plan, tree ordinances and/or policies, and advocacy or advisory group, and professional urban tree staff.