1.7 Production in an Environment of Changing Climate [Joe-Ann McCoy, Johanna Young]

Data released by NASA and NOAA scientists on January 16, 2015 have officially verified 2014 as the Earth's warmest year on record since 1880, with nine of the ten warmest years on record occurring after 2000 (Cole and McCarthy, 2015). Recent temperature trends, in addition to future climate predictions, have produced disturbing new terminology associated with climate issues which will directly affect non timber forest products (NTFP's). These include, 'zone creep', 'season creep', 'simultaneous opposing temperature extremes', 'growing adaptation deficit', 'adaptive evolution', 'spring creep', 'spring mismatches', and the 'Anthropocene'.

'Zone creep' refers to the USDA hardiness zones which when revised in 2012 and compared to the former 1990 edition illustrated a consistent trend of shifting North due to temperature fluctuations which may alter specific species and crops suitable by region. This has resulted in a significant change in planting zones, averaging a half-zone warmer per hardiness zone. The revised 2012 USDA map shows this as an average minimum temperatures rise of 5 degrees Fahrenheit across the country as compared to 1990, changing the growth boundaries and moving most of them northward. For example, Ohio was formerly within Zone 5, but now is almost entirely within the warmer Zone 6. As a result, growers and wildharvesters in these areas may have to reconsider their planting and harvesting choices in the future (Malcolm et al. 2012).

The long-term results of zone-creep will affect specific habitats associated with non-timber forest products differently, with some habitats and species being far more vulnerable to the changes (USDA, 2015). As a result, storing as much germplasm in the form of seed as possible before more changes occur and predicting where and which species need to be prioritized for conservation are essential long-term strategies.

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'Season creep' and 'spring creep' refer to differentiation of first and last frost dates which may alter pollinators and hibernation trends (Schwartz, Ahas, & Aasa, 2006; Sherry, et. al 2007). Phenology is a sensitive biosphere indicator of climate change. Long-term surface data and remote sensing measurements indicate that plant phenology has advanced by 2–3 days in spring and delayed by 0.3–1.6 days in autumn per decade in the past 30–80 years, culminating in a significant extension of the growing season in 2015. As temperatures rise, spring seasons are arriving earlier while winters are shorter and more extreme. With this "season" change frost vulnerability becomes more of a threat, where high spring temperatures create earlier flowering schedules, leaving blooms at risk of a freeze (Inouye, 2008). This is important to mountain-dwelling crops such as apple and various NTFP species, which are increasingly experiencing frequent frost damage due to early blooming**.** Increased pests are yet another result of this phenomenon, where warmer/ shorter winters provide favorable conditions for pest populations to skyrocket instead of die out over the winter (Jamieson, 2012). For example, Gypsy moths, tent caterpillars, beech bark disease, and hemlock woolly adelgids are expected to expand their ranges due to the changing seasons, effecting both crop and forest health (Dukes, 2009). Projections by the USDA speculate that the potential impact of this spread and redistribution of agricultural pests may reduce agricultural returns by $1.5 billion to $3.0 billion by 2030 (Malcolm et al. 2012).

'Simultaneous opposing temperature extremes' refer to the record hot and cold extremes of 2014 when the country experienced some of the highest recorded opposing temperature extremes in the same January-July period. At a combined 40% of the country, the area affected by extremes was nearly double the size expected (Arndt, 2014). The ‘growing adaptation deficit’ refers to the financial fact that climate change impacts are being felt on every continent, but that adaptation investments are dangerously lagging (Biron, 2014).

‘Adaptational lag’ is another concern if species can’t keep up with rapid climate change, individual populations and entire species may decline or go extinct. In a particular study, lagging adaptation to warming climate was tested among banked seeds of the annual weed *Arabidopsis thaliana* (L.) Heynh. in common garden experiments at four sites across the species’ native European climate range (Wilczek et al. 2014). Results found that genotypes originating in southern climates, historically warmer than the planting site, had higher relative fitness than native genotypes at every site. This suggests that local adaptive optima have shifted rapidly with recent climate warming across the species’ native range, and that the potential for adaptational lag deserves consideration in conservation and wild harvest management decisions for many species.

Jake Weltzin , director of the National Phenology Network, found that earlier spring dates create "spring mismatches" as some plants bud earlier and the animals that depend on them have not had the opportunity to adapt. For example, bees may target specific habitats with plant populations they historically pollinate only to find those plants have already bloomed. ‘Mismatches’ can be fatal. In numerous U.S. states, caterpillars, which were traditionally eaten by migratory birds, are now falling to the ground before the birds arrive. An associated recent study found thousands of grazing pregnant mares in the Ohio River Valley ingesting the caterpillars, which caused them to abort their fetuses (Fitzpatrick, 2010).

The ‘Anthropocene’ (Greek: anthropo- meaning ‘human’ and -cene meaning ‘new’) is a ‘new’ term for the current geologic time span that officially began when human activities produced significant global impact on the Earth's ecosystems for the first time. There is much debate on when the Anthropocene officially began, with proposed dates including the industrial revolution of the late eighteenth century, World War II when radioactive fallout contaminated soils worldwide, to the end of the last glacial period, 11.7 thousand years ago, coinciding with the onset of the Holocene (Certini, 2014).

As a result of current and future predicted climate trends, long-term effects on native NTFP’s in North America will be difficult to predict but deserve study to prepare for longterm conservation of populations. Figure 1.) illustrates current and projected forest types for North America suggesting significant changes in forest structure which will affect NTFP’s in the future (USGCRP, 2009). These predictive models will be helpful when prioritizing collection sites for conservation. Some long-term forest predictions by the EPA include: 1.) Climate change will likely alter the frequency and intensity of forest disturbances, including wildfires, storms, insect outbreaks, and the occurrence of invasive species; 2.) The productivity of forests could be affected by changes in temperature, precipitation and the amount of carbon dioxide in the air, and; 3.) Climate change will likely worsen the problems already faced by forests from land development and air pollution (USGCRP, 2009). Depending on regional hardiness zones and habitat, long-term effects will vary by species and need to be prioritized based on predicted risk factors. Long-term seed banks need to become a mandatory aspect of plant conservation as native forest species are currently under-represented in state and federal germplasm collections.

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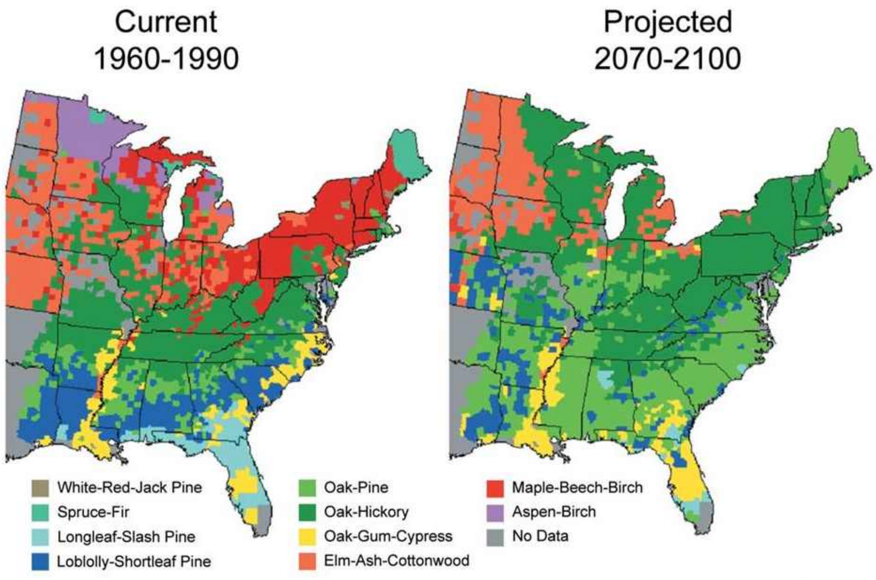

Figure 1.) The maps illustrate current and projected shifts in forest types with major changes projected for many regions. For example, in the Northeast, under a mid-range warming scenario, the currently dominant maple-beech-birch forest type is projected to be completely displaced by other forest types in a warmer future. (USGCRP, 2009)

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