

Role of Climate Change in Reforestation and Nursery Practices

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Ecosystems have been adjusting to changes in climate over time, but projections are that future global climate will change at rates faster than that previously experienced in geologic time. It is not necessarily the amount of change, but rather this rate of change that is most threatening to plant species—the climate appears to be changing faster than plants can adapt or migrate. Long-lived species, such as trees, will lag behind short-lived species in their ability to adapt and track suitable climate conditions. Although growing season length will continue to lengthen under climate change and may cause an increase in forest productivity, it will be offset by increased evaporation, transpiration, soil drying, and phenological imbalances. Expected impacts on forests are similar to what we have already observed, such as landscape-scale tree mortality due to mountain pine beetle outbreaks in the Rocky Mountains and prolonged drought and high temperatures in the southwestern US and Canadian boreal forests.

Impacts will intensify during the latter half of this century with forest systems continuing to experience shifts in phenology and distribution, making plants poorly adapted to their local climates.

The divergence in rates between climate change and tree adaptation will have important consequences for reforestation and nursery practices. Plant materials outplanted today must be able to meet and face the climatic challenges during this century. Unfortunately, most state and commercial nurseries in the US have not yet explored how changes in climate will



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Producing high-quality seedlings for reforestation will remain a priority, especially to meet the challenges of a changing climate.

impact their operations. This article highlights some adaptation strategies to help reforestation and nursery practices, such as moving populations to new locations, modifying seed transfer guidelines, and targeting diversity in plant materials.

On the move

Foresters may need to move tree populations to new locations to maintain adaptation. Assisted migration, also referred to as managed relocation and assisted colonization, is the movement of species and populations to facilitate natural range expansion in direct management response to cli-

mate change. In forestry, assisted migration can be a viable option for some tree species and populations that are at risk of decline or extirpation under climate change. Assisted migration does not mean moving plants far distances, but rather helping genotypes, seed sources, and tree populations move with suitable climatic conditions to avoid maladaptation, which will probably entail moving seeds across current seed-zone boundaries or beyond transfer guidelines.

Preliminary research on most commercial tree species demonstrates that

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target distances would be short, occurring within current ranges of those species. Researchers are also working to better understand how to use assisted migration. One project is the Assisted Migration Adaptation Trial that consists of several long-term experiments being conducted by the British Columbia Ministry of Forests, the US Forest Service, timber companies, and other partners that test assisted migration, climate change, and tree performance in the Pacific Northwest. In British

Columbia, western larch may now be moved to suitable climatic locations just outside its current range. Foresters in the southern US have been moving seed sources of southern pines one seed zone north to take advantage of changes in climate and assisted migration is being used to save Florida torreya, a rare southeastern US evergreen conifer, from extinction.

Flex the guidelines

Foresters and nursery managers will need to reconsider the selection, production, and outplanting of native trees in a dynamic context. That is, they will need to re-evaluate the practice of restricting tree movement to environments similar to the tree's source, a long-held practice in forest management. Seed transfer guidelines are needed for short- and long-term planning efforts and will require adjustments as new climate change information comes to light because using cur-



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Provenance tests that led to development of seed orchards may be a valuable resource in identifying and transferring plant materials suitable for new climates.

rent, static seed transfer guidelines and zones will likely result in trees facing unfavorable growing conditions by the end of this century. In Canada, a few provinces have already modified policies in conjunction with climate change. Alberta has extended current seed transfer guidelines northward by 2° latitude and upslope by 656 ft (200 m) and new guidelines for some species were revised upslope by 656 ft (200 m) in British Columbia.

Changing guidelines will require collaboration and discussion of how predicted conditions (warmer temperatures and variable precipitation patterns) will affect forests. Nurseries can work with foresters to explore genotypes that may be resilient to temperature and moisture extremes. Information such as where the plant comes from, where it is planted geographically, and how it performs (growth, survival, reproduction, and so on) can guide forestry practices to increase the proportion of species

that survive and grow well under varied climatic conditions. Consulting online tools, such as the Seedlot Selection Tool (<http://sst.forestry.oregon-state.edu/>)—a mapping tool that matches seedlots with outplanting sites based on current or future climates for tree species such as Douglas-fir and ponderosa pine—can help foresters make decisions about future seed transfers. Projected seed zones have been developed for a variety of trees, such as quaking aspen; lodgepole pine, longleaf

pine, and whitebark pine; western larch; and flowering dogwood. Where we lack provenance data, we can employ logic-based approaches to select optimal seed sources for current and future climates and rely on seed zones that are warmer than the target outplanting site. Seed zones and guidelines can be shifted to an amount equivalent to what we think will buffer climate change, for example, procuring plant materials from a site 1° C warmer than the outplanting site. Fortunately, many state and commercial nurseries in the eastern half of the US already carry tree species and seed sources collected from sites further south (often beyond state borders) than the anticipated outplanting sites, suggesting that

For More Information

- Assisted Migration Adaptation Trial (AMAT): www.for.gov.bc.ca/hre/for/gen/interior/AMAT.htm#Overview
- Assisted Migration/Climate Change Literature Database: www.rngr.net/publications/assisted-migration
- Center for Forest Provenance Data: <http://cenfor.gen.forestry.oregonstate.edu/index.php>
- Climate Change Resource Center: www.fs.fed.us/ccrc/
- Preparing for climate change: Forestry and assisted migration: www.treesearch.fs.fed.us/pubs/44260



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plant materials being outplanted now may be adapted to warmer conditions.

Buffer uncertainty with diversity

Conserving and maximizing genetic diversity in plant materials will provide species and populations with the adaptive and evolutionary ammunition to offset changes in climate. Genetic diversity can be conserved by protecting natural reserves in heterogeneous landscapes and collecting seeds from many populations across their geographic range for long-term storage (for example, seed banks). Guidelines that focus on increasing the genetic diversity within the deployment population provide some long-term insurance that would counter against uncertainty in climate predictions and species' reactions to climate change.

High levels of diversity may swamp the few individuals in a collection that are adapted to either the current or future climate; therefore, the level of diversity should match the level of climate uncertainty. In situations with high uncertainty, planting a mixture of seed sources and monitoring their adaptive response might be best. Disturbed areas can be used as outplanting sites to evaluate genotypes, seed source diversity, and age classes. Allowing for physiological or morphological variation in nursery stock might serve to facilitate natural selection to future climates, more so than planting stock that has uniformity in traits. Tree improvement programs can also provide opportunities to breed and select for traits such as drought tolerance.

Connecting roles

Even though an adaptation strategy, such as assisted migration, may force us to weigh options—allowing extinction and maladaptation against intro-



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Foresters have been growing and moving native plant materials for more than a century, and thus are uniquely qualified to be leaders in discussions about assisted migration as an adaptive strategy for climate change.

ducing species and populations into areas in which they are not native—a no-action approach in forestry is not sustainable. Collaboration among researchers, foresters, and nurseries and assessment of risks can help curtail significant social, economic, and ecological losses associated with impacts from a rapidly changing climate. The forestry profession, with its experience of crafting seed transfer guidelines, developing seed orchards, and maintaining vibrant forest landscapes is uniquely suited to be leaders in this endeavor. Each party plays an instrumental role, but all must be willing and open to new approaches whether it is encouraging landowners to plant for future climates or informing nurseries and clients about documenting seed source information and outplanting

performance. Nurseries should see themselves in partnerships with land managers, foresters, and restorationists and work with stakeholders to provide appropriate plant materials. Given their long history of selecting and growing trees, foresters and nursery practitioners are well-equipped to test and implement different strategies. ♦

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