Assisted Migration: What It Means to Nursery Managers and Tree Planters

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Abstract

Projections indicate that natural plant adaptation and migration may not keep pace with climate changes. This mismatch in rates will pose significant challenges for practitioners that select, grow, and outplant native tree species. Populations of native tree species planted today must be able to meet the climatic challenges they will face during this century. One strategy to meet this challenge is assisted migration, the intentional movement of plant materials in response to climate change to maximize survival and curtail maladaptation. For successful assisted migration, climate changes will need to be met by changes in ethical, legal, political, and economical paradigms, as well as with the way foresters view seed transfer guidelines. We review and explore assisted migration as an adaptation strategy, discuss the role of nurseries, present some working examples, and provide tools and resources for consultation.

Introduction

Although climate is always changing, and ecosystems have been adjusting to those changes (Davis 1990, Huntley 1991, Jansen and others 2007), the climate is now expected to change faster than trees can adapt or migrate naturally in some regions (Zhu and others 2012, Gray and Hamann 2013). As a consequence, foresters may need to assist tree species in their migration to new locations to ensure the resilience and sustainability of ecosystem services (e.g., wildlife habitat, timber production, recreation, and water and air quality) (Aubin and others 2011). Assisted migration is a complex topic rife with ethical, economical, legal, political, and ecological issues (Schwartz and others 2012); it disrupts widely held conservation objectives and paradigms (McLachlan and others 2007). Even so, assisted migration can be a viable option for some tree species and populations that are at risk of decline or extirpation under rapid changes in climate (figure 1). For a more indepth discussion, see the review by Williams and Dumroese (2013).

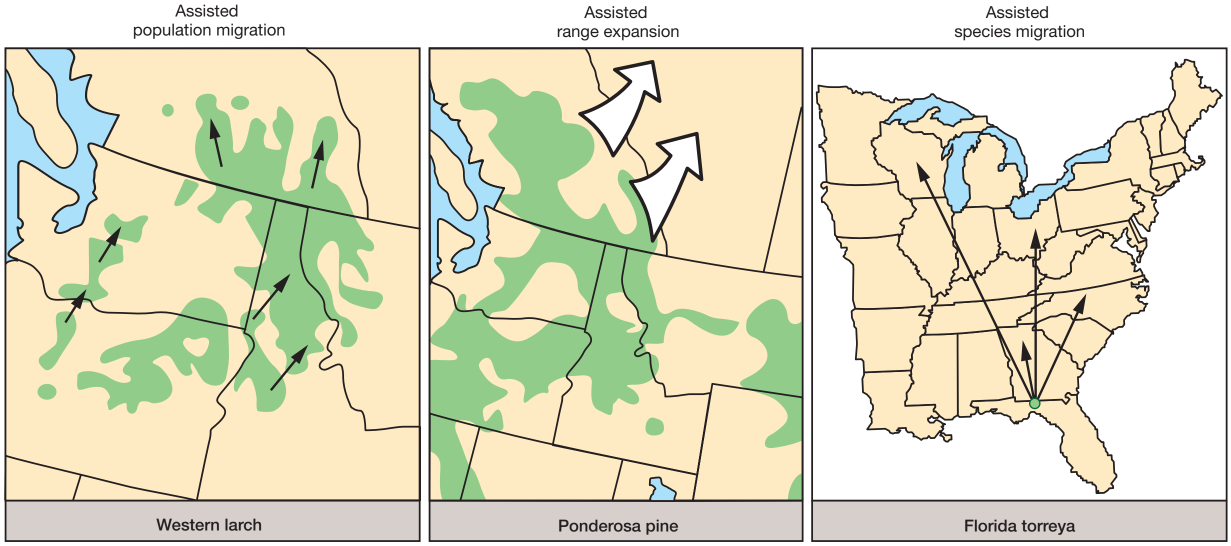

Figure 1. Seed migration can occur as assisted population migration in which seed sources are moved climatically or geographically within their current ranges (green), even across seed transfer zones; e.g., moving western larch 125 mi (200 km) north within its current range, (left). Seed sources can also be moved climatically or geographically from current ranges to suitable areas just outside the range to assist range expansion, such as moving seed sources of ponderosa pine into Alberta, Canada, (middle). For assisted species migration, species could be moved far outside current ranges to prevent extinction, such as planting Florida torreya in States north of Florida (Torreya Guardians 2008), (right). (Terms were reused from Ste-Marie and others 2011 and Winder and others 2011; distribution maps were adapted from Petrides and Petrides 1998 and Torreya Guardians 2008.)

Humans have been moving plants for a long time, and, as foresters, we have been properly moving trees by using seed transfer guidelines. Taking this process one step further, assisted migration is the intentional movement of species and populations to facilitate natural range expansion in a direct management response to climate change (figure 1) (Vitt and others 2010). Assisted migration does not necessarily mean moving plants far distances, but rather helping genotypes, seed sources, and tree populations move with suitable climatic conditions to avoid maladaptation (Williams and Dumroese 2013), which will probably entail moving seed across current seed-zone boundaries or beyond transfer guidelines (Ledig and Kitzmiller 1992). Thus, seed transfer guidelines will need to factor in climate change because using current guidelines and zones will likely result in native trees or their populations facing unfavorable growing conditions by the end of this century.

What Is the Role of Nurseries?

Nursery managers have an important role in the assisted migration process. It is unfortunate that most State and commercial nurseries in the United States have not yet explored how changes in climate will impact their operations (Tepe and Meretsky 2011). As part of the target plant concept (Landis and others 2010), however, nursery managers should see themselves in partnerships with land managers, foresters, and restorationists, and work with stakeholders to provide appropriate plant materials (i.e., seed, nursery stock, or genetic material). The matching of existing plant materials with future ecosystems that will have different climate conditions is a formidable component of assisted migration (Pedlar and others 2011, Potter and Hargrove 2012). Foresters and nursery managers will need to rethink the selection, production, and outplanting of native trees in a dynamic context. That is, they will need to reevaluate the practice of restricting tree movement to environments similar to the tree's source, a long-held practice in forest management (Langlet 1971). Nurseries can work with geneticists to explore genotypes that may be resilient to extreme temperature and moisture conditions. Using disturbed areas as outplanting sites to test assisted migration is a perfect opportunity to also evaluate genotypes, seed mix diversity, and age classes (Spittlehouse and Stewart 2003, Millar and others 2007, Jones and Monaco 2009).

Many existing provenance and common garden studies can be transformed with little modification to look at adaptation and response to climatic conditions (Matyas 1994), thereby shifting our focus to producing plant materials that grow and survive well in changing climates. Information such as where the plant comes from, where it is planted geographically, and how it performs (growth, survival, reproduction, etc.) can guide forestry practices to increase the proportion of species that thrive under new climatic conditions (McKay and others 2005, Millar and others 2007, Hebda 2008). Changing policies will require collaboration and discussion of how predicted conditions will affect forests, how nurseries can plan for the future, and how clients can be encouraged to plant trees adapted to future conditions, such as warmer temperatures and variable precipitation patterns (Tepe and Meretsky 2011). It is fortunate that many State and commercial nurseries, especially in the eastern half of the United States, already carry tree species and seed sources collected from sites farther south (often beyond State borders) than the anticipated outplanting sites, which suggests that plant materials being planted now may be adapted to warmer conditions.

Assisted Migration in Action

Assisted migration will be best implemented where seed transfer guidelines and zones are currently in place and most successful if based on anticipated climate conditions (McKenney and others 2009) because these data can be used to ensure that trees being established today will be adapted to future climates (Pedlar and others 2012). Researchers are 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 (B.C.) Ministry of Forests, the USDA Forest Service, timber companies, and other partners. The experiments test assisted migration, climate change, and tree performance in B.C. and the Pacific Northwest region (table 1) (Marris 2009). Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) has also been planted around the Pacific Northwest region to evaluate its growth response to climatic variation (Erickson and others 2012). To test species range limits in Quebec, Canada, northern sites are being planted with a mixture of seed sources from the southern portion of the province.

Preliminary research on most commercial tree species in Canada demonstrates that target migration distances would be short, occurring within current ranges of those species (O'Neill and others 2008, Gray and others 2011). For some tree species, target migration distances are less than 125 mi (less than 200 km) north or less than 328 ft (less than 100 m) up in elevation during the next 20 to 50 years (Beaulieu and Rainville 2005, O'Neill and others 2008, Pedlar and others 2012, Gray and Hamann 2013). Several Canadian provinces subsequently have modified seed transfer policies to be more dynamic and in conjunction with climate change. Alberta has extended current seed transfer guidelines northward by 2° latitude and upslope by 656 ft (200 m) (NRC 2013) and new guidelines for some species were revised upslope by 656 ft (200 m) in B.C. (O'Neill and others 2008). Also in B.C., western larch (*Larix occidentalis* Nutt.) may now be moved to suitable climatic locations just outside its current range (NRC 2013). In a similar vein, foresters in the Southern United States have been moving seed sources of southern pines one seed zone north to take advantage of changes in climate (Schmidtling 2001). Assisted species migration is being used to save Florida torreya (*Torreya taxifolia* Arn.), a rare Southeastern United States evergreen conifer, from extinction (McLachlan and others 2007, Barlow 2011).

Table 1. Resources related to forest management, native plant transfer guidelines, climate change, and assisted migration for the United States and Canada. Most programs are easily located by searching their names in common Web browsers. All URLs were valid as of October 15, 2013. Reprinted from Williams and Dumroese (2013).

Resource or program	Description	Authorship
Assisted Migration Adaptation Trial http://www.for.gov.bc.ca/hre/forgen/interior/AMAT.htm	Large, long-term project to evaluate the response of 15 tree species to climate change and assisted migration	Ministry of Forest and Range, British Columbia
Center for Forest Provenance Data http://cenforgen.forestry.oregonstate.edu/index.php	Online database where public users can submit and retrieve tree provenance and genecological data	Oregon State University and USDA Forest Service
Centre for Forest Conservation Genetics http://www.genetics.forestry.ubc.ca/cfcg/	Portal for forest genetics and climate change research conducted in British Columbia, Canada	The University of British Columbia
Climate Change Response Framework http://climateframework.org/	Collaborative framework among scientists, managers, and landowners to incorporate climate change into management	Northern Institute of Applied Climate Science
Climate Change Tree Atlas http://www.nrs.fs.fed.us/atlas/tree/tree_atlas.html	An interactive database that maps current (2000) and potential status (2100) of Eastern U.S. tree species under different climate change scenarios	USDA Forest Service
Forest Seedling Network http://www.forestseedlingnetwork.com	Interactive Web site connecting forest landowners with seedling providers and forest management services and contractors; includes seed zone maps	Forest Seedling Network
Forest Tree Genetic Risk Assessment System (ForGRAS) http://www.forestthreats.org/research/projects/project-summaries/assessing-forest-tree-risk	Tool to identify tree species risk of genetic degradation in the Pacific Northwest and Southeast Regions	North Carolina State University and USDA Forest Service
MaxEnt (Maximum Entropy) http://www.cs.princeton.edu/~schapire/maxent/	Software that uses species occurrences and environmental and climate data to map potential habitat; can be used to develop seed collection areas	Phillips and others (2006)
Native Seed Network http://www.nativeseednetwork.org/	Interactive database of native plant and seed information and guidelines for restoration, native plant propagation, and native seed procurement by ecoregion	Institute for Applied Ecology
Seed Zone Mapper http://www.fs.fed.us/wwetac/threat_map/SeedZones_Intro.html	An interactive seed zone map of western North America that displays political and agency boundaries, topography, relief, streets, threats, and resource layers and where user selects areas to identify provisional and empirical seed zones for grasses, forbs, shrubs, and conifers	USDA Forest Service
Seedlot Selection Tool http://sst.forestry.oregonstate.edu/index.html	An interactive mapping tool to help forest managers match seedlots with outplanting sites based on current climate or future climate change scenarios; maps current or future climates defined by temperature and precipitation	Oregon State University and USDA Forest Service
SeedWhere https://glfc.cfsnet.nfis.org/mapserver/seedwhere/seedwhere-about.php?lang=e	GIS tool to assist nursery stock and seed transfer decisions for forest restoration projects in Canada and the Great Lakes region; can identify geographic similarities between seed sources and outplanting sites	Natural Resources Canada, Canadian Forest Service
System for Assessing Species Vulnerability (SAVS) http://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/	Software that identifies the relative vulnerability or resilience of vertebrate species to climate change; provides a framework for integrating new information into climate change assessments	USDA Forest Service

GIS = geographic information system. USDA = U.S. Department of Agriculture.

New Tools for Determining Proper Seed Transfer

Target migration distances are needed for short- and long-term planning efforts and will require adjustments as new climate change information comes to light. To guide seed movement under climate change, methods using transfer functions and provenance data have been developed (e.g., Beaulieu and Rainville 2005, Wang and others 2006, Crowe and Parker 2008; Thomson and others 2010, Ukrainetz and others 2011). Projected seed zones have been developed for a variety of trees, including commercial species such as quaking aspen (*Populus tremuloides* Michx.) (Gray and others 2011); lodgepole pine (*Pinus contorta* [Douglas ex Loudon]) (Wang and others 2006), longleaf pine (*P. palustris* Mill.) (Potter and Hargrove 2012), and whitebark pine (*P. albicaulis* Engelm.) (McLane and Aitken 2012); western larch (Rehfeldt and Jaquish 2010); and noncommercial species such as flowering dogwood (*Cornus florida* L.) (Potter and Hargrove 2012).

Canada and the United States have online tools to assist forest managers and researchers in making decisions about matching seedlots with outplanting sites. For Quebec, Optisource (Beaulieu 2009) and BioSim (Regniere and Saint-Amant 2008) are useful tools. In Ontario, SeedWhere can map potential seed collection or outplanting sites based on climatic similarity of chosen sites to a region of interest (McKenney and others 1999). In the United States, the Seedlot Selection Tool (Howe and others 2009) is 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 (*Pinus ponderosa* Lawson & C. Lawson). Because of the lack of seed transfer guidelines and zones for noncommercial tree species, the best we can do currently is consult provisional seed zones (e.g., Seed Zone Mapper—table 1) developed from temperature and precipitation data and Omernik level III and IV ecoregion boundaries (Omernik 1987).

Final Remarks

Climate change poses a substantial challenge for foresters, but given their long history of selecting and growing trees, the forestry profession has the knowledge, skills, and tools to test and implement assisted migration. Researchers, foresters, and nursery managers can work together to begin discussing and implementing climate change adaptation strategies, such as assisted migration, and hopefully curtail significant social, economic, and ecological losses associated with impacts from a rapidly changing climate. Whatever the chosen adaptive strategies may entail, forest and conservation nurseries need to be included in the dialogue for climate change planning because this collaboration is key to successfully producing native trees to sustain future ecosystems (McKay and others 2005).

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