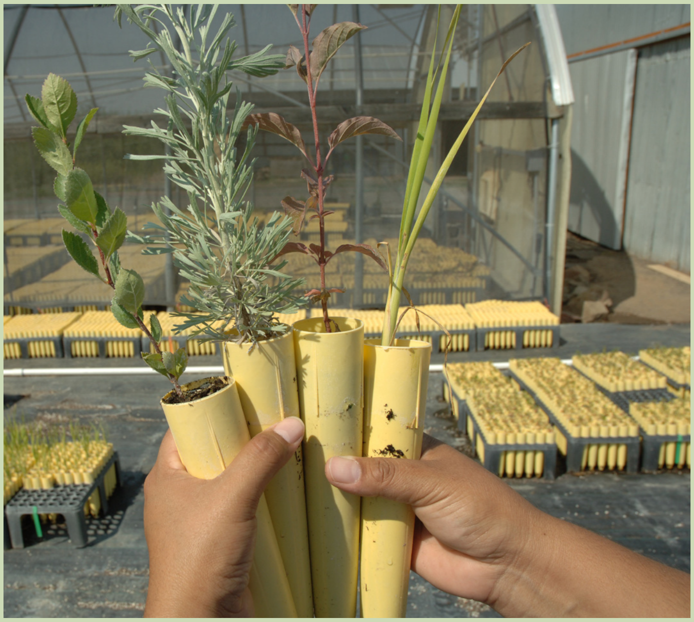

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Selecting NATIVE PLANT MATERIALS for restoration projects

Ensuring local adaptation and maintaining genetic diversity

B. Withrow-Robinson and R. Johnson

Selecting appropriate plant materials for restoration projects contributes to the success of the project by ensuring better adaptation and survival of the plants. "Appropriate" means choosing species that are suitable for the site, are grown from locally adapted sources, and have a solid genetic base.

This publication is for people involved in the important task of rehabilitating and restoring Oregon's threatened or degraded habitats. Growing numbers of private landowners, local organizations, and government entities are embarking on projects to restore the health or function of their riparian areas, wetlands, prairies, savannas, and other habitats. Choosing the right plants is critical to the long-term success of these projects, but it is not always as straightforward as it seems. Managers often lack a strong background in genetics and may be confused by competing (and sometimes conflicting) claims when collecting or buying seeds, seedlings, or other plant materials.

Note: This publication does not apply to the conservation of rare or endangered species, for which the genetic considerations are much more specific.

The purpose of this publication is to help restoration managers ask and respond to two important questions:

1. Where should our plants come from; or, more specifically, what are the appropriate sources of origin for the plants to be used in our project?
2. Are we maintaining adequate genetic diversity in the plant materials we introduce?

In this publication, we describe important concepts, such as **source of origin**, and management mechanisms, such as **transfer guidelines**. (Terms in **bold** are in the glossary, page 9.) Other commonly used terms such as "native" and "local" have vague or imprecise meanings and are discussed in the context of plant selection.

Although plant material selection is an important step in restoration planning and implementation, it is but one part of the larger process that begins with defining your restoration objectives and considering the existing site conditions. We touch only briefly on those topics.

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Setting objectives

Restoration can be a long and complicated process. Success depends not only on selecting the appropriate species and right plant materials but also on identifying clear and realistic objectives for your site. Aiming to restore a highly disturbed site to a "pristine," "natural," or even "historic" condition may be an appealing goal, but it's often beyond the reach of most projects. It is more practical to think in terms of restoring specific ecological functions and then working to establish the vegetation that will create conditions that provide those functions. For example:

Target ecological function	Strategy
Increase the amount of shade or shelter on a stream	Plant trees along the bank
Provide tree cavities for nesting structures that certain birds need	Create snags
Provide food sources for a particular insect	Maintain specific host plants

By identifying restoration objectives first, it becomes easier to select the appropriate plant species to fulfill the desired ecological functions. You also need to consider the conditions of the site—such as soil type and drainage, elevation, disturbance patterns, and weeds and other competing vegetation—which are important factors in choosing plants species that will perform well on the site. The planting decision also will reflect choices among different plant materials: seeds, cuttings, or seedlings, and even the type of seedlings.

Many local resources are available to help you choose plant species and materials suited to a restoration site and your objectives there. County offices of the Oregon State University Extension Service and local offices of the county Soil and Water Conservation District (SWCD), the USDA Natural Resources Conservation Service (NRCS), and local chapters of the Native Plant Society of Oregon can provide helpful information (see "For more information," page 9).

Beyond deciding what species to plant, or even what plant material to use, it is important for restoration managers to consider the genetics of the plant materials they are collecting or buying. This ultimately may determine the success of the project.

Figure 1.—The source of origin of plant material is the geographic area where the seeds or cuttings were collected originally.

Plant materials' source of origin

It is important to know the **source of origin** of plant materials; that is, the geographic area where the seeds or cuttings were collected originally. This is not to be confused with the place where the plants were grown or propagated (such as a nursery). The source of origin tells something about the genetic background of the plant materials and can help inform you on how well adapted this material may be for your site. The location of the nursery does not tell you this. Choosing plants from a known and appropriate source of origin can help ensure better long-term adaptation to your local conditions. But what makes a source appropriate, and how do you find materials from that source?

Experience from tree-planting projects has demonstrated that a project can fail if it uses seed or seedlings that were gathered from trees growing too far away from the project site where they finally were planted. The trees introduced to the project site were not well adapted to their new home. We now have various methods to guide transfer of forest tree materials from place to place, but guidelines are lacking for most native grasses, forbs, and shrubs used in restoration activities. As a result, it is quite easy for plants of inappropriate or unknown origin to be sold and planted in local restoration projects, even though the plants are being identified as "native." This should cause concern among managers.

So what is "native"?

Although frequently used, "native" is not very precisely defined, and the term means different things to different people. It commonly is used to mean those species that were in a place (here in Oregon) before European settlement introduced plants from distant areas. But native does not necessarily mean local. Many natives, including trees and shrubs common in riparian communities, are widely distributed across western North America. Familiar native Oregon trees such as Douglas-fir *(Pseudotsuga menziesii)*, ponderosa pine *(Pinus ponderosa)*, western white pine *(Pinus monticola)*, Oregon white oak *(Quercus garryana)*, and black cottonwood *(Populus trichocarpa)* all have ranges from Canada to Mexico and, in some cases, from the Pacific to beyond the Rocky Mountains. Many herbaceous plants, such as yarrow *(Achillea millefolium)* also have very broad distributions. Each is native to and survives in a wide range of conditions across a broad landscape in and beyond Oregon. This is possible because populations of each species have adapted to local conditions, which vary with elevation, latitude, rainfall, temperature, and much more. That is not to say that every member of that species will thrive or even survive in all those places. Again, native does not necessarily mean local.

So what is "local"?

If native does not mean local, how does one define local? The scholarly literature has many articles asking the question "How local is local?" Unfortunately there is no simple definition that applies to all species, but we do know that nonlocal kin often are not as well adaptated as local populations. For example, plants from Mount Hood would not be expected to adapt well to the Coos Bay area, even if the species grows in both locations; the climates and soils to which the local populations have adapted are very different. This principle has been illustrated through decades of experience with forest tree species in the United States and Europe. A local illustration of the importance of using local seed sources was the replanting of the Tillamook Burn (Figure 2). Trees from more distant sources, such as the east slopes of the Cascades, did not perform as well in the moist, coastal mountains of Tillamook as trees from nearer seed sources, such as the Mount Hebo area. This and other experiences in forestry indicate the importance of paying strict attention to source of origin when planting native materials in restoration activities!

Identifying "locally adapted" plant materials

Once we recognize the need to use native species of local origin, an important question becomes "How far can a plant be moved and still, in its new location, behave like a local?" To help answer that question, geneticists have developed **transfer guidelines**. A common kind of transfer guideline is the U.S. Department of Agriculture plant hardiness zone map. Many gardeners rely on this map, based on winter minimum temperatures, to guide their selection of plants that can grow successfully in their area.

Figure 2.—Replanting the Tillamook Burn illustrated the importance of using local seed sources. Trees from more distant sources did not do as well as trees from nearer seed sources. Photo courtesy of Oregon Department of Forestry Tillamook Forest Center.

Transfer guidelines

It would be nice if we had a consistent distance, some magic number (say, within a 50-mile radius), to indicate how far a plant might be moved successfully, but it is not that simple. For plants, "local" is best defined ecologically, in terms of climate and environment, rather than in miles. For example, the environments of Coos Bay and Astoria (200 miles apart) are much more similar than the environments of Coos Bay and Roseburg (just 50 miles apart). The conditions to which a plant species must adapt (and what make Coos Bay more similar to Astoria than Roseburg) include rainfall, summer and winter

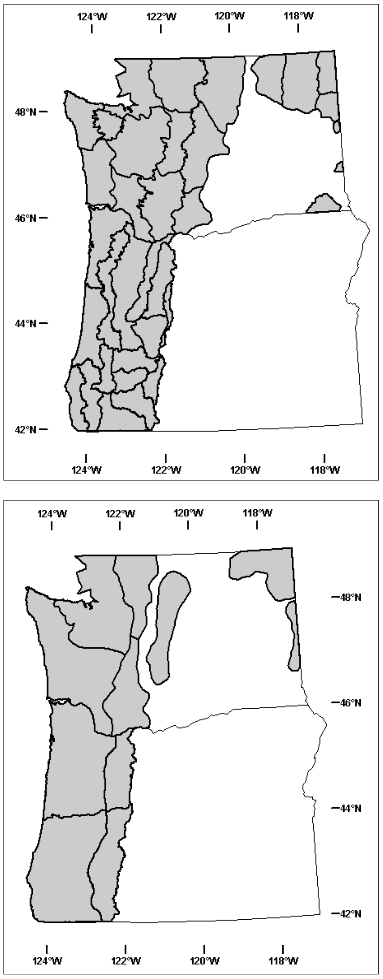


Figure 3.—Seed zone maps of Oregon and Washington for Douglas-fir (at top), which is a site specialist, and western redcedar, a site generalist.

temperatures, aspect (the direction in which the site faces), soil drainage, and soil pH.

Another issue is that the scope of adaptation varies greatly among species. Some plants (called site generalists) can be moved much farther than others (called site specialists) and still adapt well to local conditions and regions. This is illustrated in Figure 3, which shows seed zones developed for two important native tree species, western redcedar *(Thuja plicata,* a site generalist) and Douglas-fir (a site specialist). Thus, transfer guidelines vary from species to species and from region to region.

Much of the available literature on seed source movement focuses on trees because more research has examined transferring timber species, but the principles are valid for most plants. Developing useful transfer guidelines is a slow process and can incorporate several approaches such as **common-garden** studies, provenance trials, and computer models. Guidelines so far have been developed for only a small number of native plants in Oregon, primarily forest trees, although work is now underway on important herbaceous species such as Roemer's fescue *(Festuca roemeri)* and blue wildrye *(Elymus glaucus).*

Seed zones

The seed zone is a common type of transfer guideline that managers use to identify appropriate sources of plant materials. A seed zone is an area with fixed boundaries on a map, within which plant materials can be transferred with little risk of adapting poorly to their new location. Figure 3 shows seed zones for Douglas-fir and western redcedar. These zones represent areas of fairly uniform environmental conditions but, more important, identify areas where individuals in a given species behave similarly. In mountainous regions, each zone is further subdivided with **elevation bands** to better define areas with similar conditions. Research and experience have shown that a 1,000-foot difference in elevation can be more important to adaptation than 100 miles of horizontal distance.

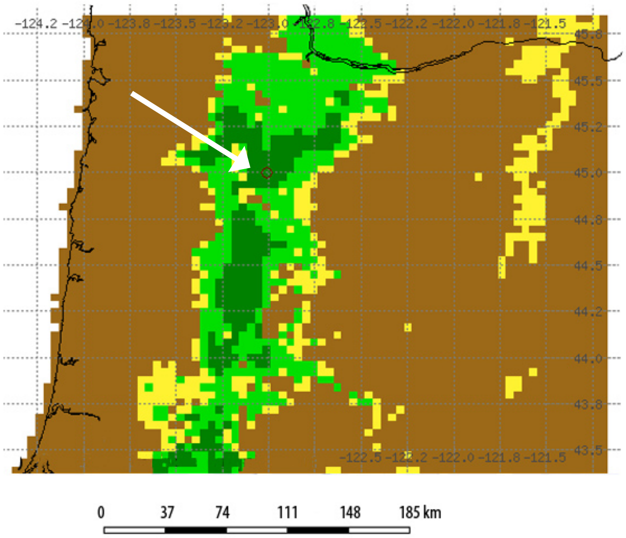
Seed zone maps are not perfect indicators—site conditions and the **adaptive traits** of plants usually vary continuously across the landscape rather than by distinct boundaries as depicted on seed zone maps. Nonetheless, seed zones are commonly and successfully used for forest tree species because they are easy to use. Forest tree seeds generally are collected according to, and nursery materials are identified by, their seed zone of origin. These collections are from many individual trees, and the plants propagated from these seeds generally perform well across the entire zone. As a result of the development and acceptance of this mechanism, it is easy to find tree seedlings of an appropriate source of origin for most parts of Oregon and Washington "on the shelf," readily available for purchase. However, for many other species of interest to restoration managers, it can be very difficult to find plant materials of *known* origin. Seed zones or other mechanisms need to be adopted for other species used in restoration work to ensure that the source of origin of the plant materials we are buying is within a certain, appropriate area.

Seed zones for tree species

Seed zones have been developed and recently revised for many tree species in Oregon and Washington, including species very appropriate for riparian restoration projects such as red alder *(Alnus rubra)*, western redcedar, western hemlock *(Tsuga heterophylla*), and Douglas-fir. For more detailed information on understanding and using seed zones, see:

- *Selecting and Buying Quality Seedlings,* EC 1196—practical information about seed zones and buying nursery seedlings (mostly conifers).
- "Forest Tree Seed Zones for Western Oregon" (1996) by W. K. Randall—has an excellent discussion about transfer guidelines. Includes seed zones for particular species.

See "For more information," pages 9–10.



Species suitability
- Not suitable
- Marginal
- Moderate
- Well

Figure 4.—A map of areas with climate similar to that of a given restoration site (shown within circled area). Map © 2005, Spatial Climate Analysis Service.

Tracking sources

The Native Seed Network is a collaborative partnership whose mission is to improve the supply and management of locally sourced native plant materials for restoration and rehabilitation. The Network helps manage native plants as a genetic resource by providing a means to track the source of plant materials offered by producers. It is a resource for managers looking to buy plant materials, particularly native herbaceous prairie and wetland plants. The Native Seed Network tries to facilitate the development of commercial sources of locally sourced native plant materials by maintaining a website— www.nativeseednetwork.org/ —with seed listings and vendor contact information.

The Oregon Seed Certification Service, part of OSU Extension, can provide third-party certification of source of origin, genetic identity, and genetic purity of collected-in-the-wild or propagated plant materials. Certification is done under the guidelines of the Association of Official Seed Certifying Agencies (AOSCA) Native Plant Connection for Pre-Varietal Germplasm (including the Source-Identified Class). For more information, visit www.oscs.orst.edu/

Several organizations, including the Native Seed Network and the Oregon Seed Certification Service, have established systems to track the collection and propagation of native species by individual seed lots. This provides the necessary source-of-origin information needed to employ any of the transfer guideline approaches described here.

Focal point seed zones

Other types of seed movement guidelines include *focal point seed zones* which have been developed for some species. The focal point seed zone delineates areas where adapted seed can be collected for use in a specific planting location. The formulas used to identify focal point seed zones typically involve climate and environmental variables that have been shown to influence traits related to adaptiveness (growth rates, growth rhythm, cold hardiness, etc.). For most species, the genetic data to form focal point seed zones are not available, but you still can examine the similarities between the source of origin and the planting site. When you have a choice of seed sources, choose the one most similar to the planting site. Important climatic variables to examine include rainfall, winter minimum temperatures, summer maximum temperatures, and soil types. Figure 4 shows an example of using the Species Suitability Model, developed by OSU's PRISM Group for the Forage Information System, to map areas with similar climates. The different colors represent the degrees to which certain variables—annual precipitation, January minimum temperatures, and July maximum temperatures—of a restoration site (within circle) correspond to those of surrounding areas. Often, however, these variables are not readily available, and you must use surrogates.

Ecoregions as surrogates

Another potential guide to transferring plant materials is to use **ecoregions** instead of seed zones, or at least as initial seed zones. An ecoregion is a defined area within which the characteristics of geography, climate, vegetation, and soil drainage are similar. An ecoregion is divided into levels, each level representing an increasing degree of detail delineating the similarity among these characteristics.

The ecoregion map developed by the U.S. Environmental Protection Agency (EPA) has four levels, from coarse (Level I) to fine scale (Level IV). When other transfer guidelines are not available, EPA Level III ecoregions, in conjunction with elevation bands, may be able to serve as surrogate seed zones to guide movement until research-based zones can be developed. The research-based forest tree seed zones generally are smaller (that is, more finely divided) than Level III ecoregions. Thus, using Level III ecoregions as seed zone surrogates might best be considered a minimum starting point for guiding source selection when other transfer guidelines are lacking for a given species. Oregon has 10 Level III ecoregions including the Coast Range, the Willamette Valley, and the Blue Mountains (Figure 5). See Thorson et al., "Ecoregions of Oregon," page 10, for more detailed information.

Tendencies and consequences

Because research-based transfer guidelines are not available for most native plants used in restoration, the seed source issue often is overlooked. This can lead to choices at one of two mistaken extremes.

One is to stretch project funds by buying whatever native plants are inexpensive or readily available on the market. This can lead to the introduction of inappropriate, poorly adapted plant materials.

The other mistake is to rigidly restrict acquisition of plant materials to those from the project site or its immediate proximity. This can lead to loss of genetic variation (see below), if the original population was small already, and/or it can lead to excessive costs and delays because of requiring separate harvest, storage, and management of populations that are not significantly different. Besides increasing the cost and difficulty of developing many seed releases for a single species, overly restrictive seed movement requirements reduce the project areas that can be undertaken. Neither extreme is a very satisfactory solution.

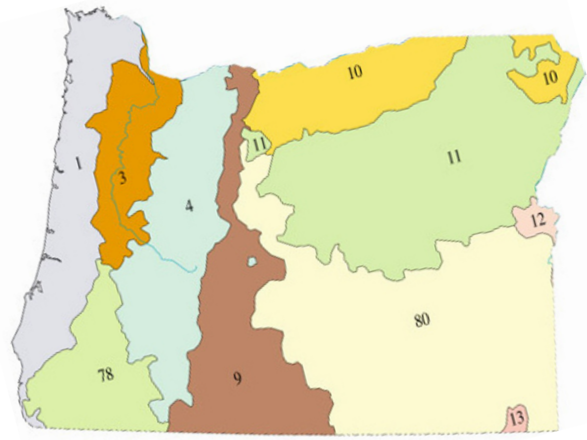


Figure 5.—Level III ecoregions of Oregon. From http://www.hort.purdue.edu/newcrop/cropmap/oregon/maps/OReco3.html

Until genetic data are available for each native species, we will need to make intelligent use of the tools we have. As discussed, these tools include the generalized zones proposed by Randall, a fairly safe and conservative option (see "Seed zones for tree species," page 4, and "For more information," pages 9–10), ecoregions, or the delineation of areas with similar climates and environments as the planting area. A century of forestry experience tells us that source of origin is an important issue that the restoration community should not ignore.

Genetic variation

Another important issue in selecting plant materials is maintaining **genetic variation** in the populations established in the restored area. Plant populations must be genetically variable to be able to adapt to new stresses. Collection and propagation procedures need to conserve sufficient genetic diversity to buffer environmental changes in both the short term (years) and long term (decades or centuries). Also, a sufficient number of unrelated seed parents will ensure that inbreeding will not become a problem in **outcrossing species**.

Both issues come down to numbers; that is, the more plants that contribute to the new population, the more genetic variation will be captured and the lower the likelihood that close relatives will mate (i.e., less inbreeding). Managers need to consider these matters, whether they are buying plant materials or collecting their own.

Failing to consider the genetic base when selecting plant materials can have potentially significant consequences on the viability and sustainability of restoration efforts. Yet it is easy to imagine how genetic variability can be eroded. Do these scenarios sound familiar?

- A local nursery grower, proud of the quality of her plants, collects her own seeds for the native trees and shrubs she raises. She collects all her Pacific dogwood *(Cornus nuttallii)* seed from two handsome, open-grown trees at a local park. They are the only Pacific dogwoods in the area.
- A native plant nursery has established cutting beds for some trees and shrubs. Several shrubs including snowberry *(Symphoricarpos albus)*, salmonberry *(Rubus spectabilis)*, and twinberry *(Lonicera involucrata)* were collected in the immediate area, from only a couple of mother plants of each species.
- Red-osier dogwood *(Cornus stolonifera)* cuttings were taken from an earlier conservation planting established from potted plants bought from a major nursery.

In all three of these scenarios, the genetic variation of the plants propagated has been greatly reduced in the collection step by not collecting from a sufficient number of parents. In the case of the Pacific dogwood propagated from seed, inbreeding also is likely. The red-osier dogwood case illustrates that a plant's original source of origin could be very different from its collection location. This plant has a huge native range that covers most of the United States, and the horticultural varieties include selections from throughout the country. So here is a case where the "native" plant could be anything but local.

How much is enough?

Plants have a wide variety of life histories with different reproduction, pollination, and breeding strategies. No single collection and propagation checklist will ensure the genetic integrity of all types of plants used in restoration, but it's important to consider the following aspects.

Number of parents

Genetic theory indicates it's best to have a *minimum* of 20 *unrelated* seed parents represented in a collection in order to capture most of the genetic variation in that population. Similarly, at least 20 individual parents should be included in cutting beds of clonally propagated species. When the amount of seed or successfully rooted cuttings produced by parent plants is highly variable, a larger number of parent plants (more than 20) would be needed to effectively capture most of the genetic variation of a population.

Figure 6.—A typical restoration site, soon after planting. Maintaining genetic variation in restored populations is very important, both as a buffer against short- and long-term environmental changes and to reduce problems of inbreeding.

Source sites (stands)

To represent a plant population well, seed or cuttings must be collected from multiple sites within the zone. Multiple parents should be sampled from each site. Seek out the larger communities, to help avoid inbreeding and meet parent-selection criteria (below).

Individual parents within a selected source

Individual maternal parents ("seed trees") should be well separated from one another yet not isolated from other trees. This increases the probability that the selected trees are unrelated and encourages cross-pollination by numerous paternal parents. Collect from many parents—at least five, but ten would better sample a population. Collect a similar amount of seed from each parent.

Figure 7.—White alder (above and inset) is a widespread species that is well adapted to riparian conditions in the Willamette Valley.

A case study

White alder in the Willamette Valley

A recent example of the construction of a locally adapted source of plant material with adequate genetic variation is that of white alder *(Alnus rhombifolia)* for the Willamette Valley.

A group of several organizations in Yamhill County wanted to have white alder available for local plantings. It is a widespread species, well adapted to riparian conditions in the Willamette Valley, but not widely available. The organizations consulted with several forest geneticists to address both source and genetic diversity concerns. On the geneticists' advice, they chose to make a seed zone collection and decided that the Willamette Valley, rather than a smaller area initially identified, was a suitable zone. White alder is found only at low elevations in the Valley, so elevation bands were not needed.

The collection strategy was to gather seed from at least 20 parent trees, in four to six stands scattered around the Valley. There were no hard-and-fast rules about choosing suitable source stands, except that each needed to be large enough to allow the selection of about five seed trees from that stand. Selected parent trees needed to be well separated from one another (about 100 feet apart) but not isolated; each needed to be among other trees that could serve as pollinators. Thus each seed parent tree (maternal) likely was pollinated by several different parents (paternal). Finding stands that met these criteria was more challenging than expected, because white alder tends to grow in clumps and in narrow ribbons along streams. Sites in several counties were identified in order to reach the population base needed.

Now, white alder seed is available to conservation groups and native plant nurseries in the area. The collection represents most of the genetic variation of the natural population and, because it is a seed zone collection, is suitable for growing throughout the Willamette Valley.

Glossary

Adaptive traits Plant characteristics that are important in determining whether the plant is adapted to its environment. Examples include cold hardiness and bud-burst date, traits important to survival in environments with cold spring weather.

Common-garden study A study in which populations from differing *sources of origin* are planted in a common environment (such as a nursery bed). Differences found among populations then can be attributed to their genetic makeup since they all are experiencing the same environment.

Ecoregion An area that contains similar ecosystems. The ecoregions developed by the U.S. Environmental Protection Agency are "areas within which biotic, abiotic, terrestrial, and aquatic capacities and potentials are similar" (McMahon et al. 2001).

Elevation bands The land that lies between two elevation levels. For example, a 1,000-foot elevation band is the area between 1,000 and 2,000 feet above sea level.

Genetic diversity (Genetic variation) The amount of variation found in the genes of a plant population. The variation we see in plants is a function of the genes that make up the plant and of the environment in which it grows. Genetic variation is the foundation that allows plants to adapt to changes in their environment. The more genetic variation available, the better the chance a population will have the right genes to adapt to a change.

Outcrossing species Plant species that rely mainly on receiving pollen from different plants to pollinate ovules in order to form seed. This contrasts with inbreeding species that rely primarily on self-pollination to form seed.

Plant materials A general term that refers to any number of plant forms used to establish a new plant. These include seeds, seedlings (bareroot, container, etc.), and cuttings.

Seed zone An area with fixed boundaries on a map, within which plant materials can be transferred with little risk that they will adapt poorly to their new location.

Source of origin The original location where plant materials were collected. It is where the seed source had developed over time and to which it is assumed to be adapted. For example, if a nursery collects wild seed from the Illinois Valley and grows it out for increase in the Willamette Valley, the *source of origin* would be the Illinois Valley.

Transfer guidelines Any guidelines used to restrict movement of plant materials to ensure that plants will be adapted to their new environment. These include *seed zones*, cold hardiness zones, focal point seed zones, and expert systems.

For more information

Exension publications

OSU Extension publications can be viewed and downloaded, and printed copies can be ordered, through the Extension website at http://extension.oregonstate.edu/catalog/

Duddles, Ralph E. and Chal Landgren. *Selecting and Buying Quality Seedlings*, EC 1196.

Emmingham, William H., Brian D. Cleary, and David R. DeYoe. *Seedling Care and Handling*, EC 1095.

Other publications

McMahon et al. 2001. Developing a spatial framework of common ecological regions for the conterminous U.S. *Environmental Management* 28:293–316.

Randall, William K. 1996. *Forest Tree Seed Zones for Western Oregon: Commercially planted forest tree species and other species commonly used in wildlife and riparian plantings.* Salem: Oregon Department of Forestry.

Online resources

California Spatial Information Library. California tree seed zones.
http://casil-mirror1.ceres.ca.gov/casil/uncategorized/legacy.ca.gov/Biology_Terrestrial/tree_seed/

Native Plant Society of Oregon.
http://npsoregon.org/

The Native Seed Network.
www.nativeseednetwork.org/

Oregon Department of Forestry. Oregon tree seed zones.
http://www.oregon.gov/ODF/FIELD/Nursery/ZoneMaps.shtml

Oregon Department of Forestry. *2006–07 Sources of Native Forest Nursery Seedlings.* Annually revised catalog can be viewed and a copy printed.
http://www.oregon.gov/ODF/PRIVATE_FORESTS/docs/2006seedlings.pdf

Oregon State University Seed Certification.
http://www.oscs.orst.edu/

Oregon State University Spatial Climate Analysis Service (SCAS). Climate and soils data for any location in the United States.
http://mistral.oce.orst.edu/forages/

Thorson, T.D., S.A. Bryce, D.A. Lammers, A.J. Woods, J.M. Omernik, J., Kagan, D.E. Pater, and J.A. Comstock. 2003. *Ecoregions of Oregon* (color poster with map, descriptive text, summary tables, and photographs). Reston, VA: U.S. Geological Survey (map scale 1:1,500,000).
http://www.epa.gov/wed/pages/ecoregions/or_eco.htm

U.S. National Arboretum. USDA Plant Hardiness Zone Maps.
http://www.usna.usda.gov/Hardzone/ushzmap.html

Figure 8.—Success in restoring sites has a lot to do with selecting "appropriate" plant materials; i.e., species that are suitable for the site, are grown from locally adapted sources, and have a solid genetic base.

USDA Natural Resources Conservation Service Plants Database.
http://plants.usda.gov/

VegSpec, a Web-based tool for selecting appropriate species and creating vegetative designs; sponsored by the USDA Natural Resources Conservation Service, the U.S. Geological Survey, and the U.S. Army Corps of Engineers.
http://vegspec.nrcs.usda.gov/vegSpec/index.jsp

Washington State Department of Natural Resources. Washington tree seed transfer zones.
http://www.dnr.wa.gov/webster/seedzonebook/

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