N A T U R A L   R E S O U R C E S

WASHINGTON TREE SEED TRANSFER ZONES

Summer 2002

WASHINGTON STATE DEPARTMENT OF
Natural Resources

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Introduction

Choosing the appropriate seed to reforest a particular site is important for many reasons: producing a long-lived, healthy stand; limiting damage from climate or pests; promoting rapid production of commodities; and maintaining locally adapted gene pools. This document will provide information to land managers responsible for selecting forest tree seed for reforestation. The risk of moving seed from a source environment to a planting environment will be kept within acceptable levels by establishing seed zones and elevation bands within which seed can be transferred. These recommendations will supersede those of the Tree Seed Zone Map that was published for the State of Washington in 1966 (see next page). They apply to seed collected from natural populations of native forest trees unless otherwise noted.

New tree seed zones or seed transfer guidelines are needed because the ones in current use are out of date. The old Tree Seed Zone Map was based only on climatic, vegetative, and topographic information. Now genetics information, which has accumulated over the past 30 years, needs to be incorporated into the recommendations. For example, the old tree seed zones were the same for all species, but it is now known that species differ tremendously in how far they can be moved safely. This guide summarizes published seed zone literature, seed transfer rules, genetics, and geographic variation for tree species used in reforestation, wildlife, and riparian planting. Specific guidelines are given for each species.

These guidelines are meant to improve silvicultural prescriptions, not to replace them. Not all sites within a seed zone will be appropriate for a particular tree species. You must rely on your knowledge of species characteristics to determine which species is most appropriate for the site you plan to reforest. To determine the best source of seed for the area you want to plant, locate the page reference for that species in the table of contents and read the specific recommendation. Then refer to the species map for seed zones and elevations bands. Elevation bands are not mapped, but are considered in the seed transfer guidelines. Also, seed zones are only delineated for areas where the species naturally occurs.

Each of these guidelines are for a particular forest tree species and should not be used for other plants. However, the 1966 Tree Seed Zones encompass areas where environmental variation is fairly uniform and could serve as guidelines for other species where no seed zones have been established.

History of Seed Zones

Foresters in the Pacific Northwest gained an appreciation of the importance of seed source as a result of large scale tree planting following major fires in the 1920s, 30s, and 40s. Seed source was often ignored at that time, and there are now numerous examples around the region of plantations where survival and growth are less than optimum because they were established with a poor seed source. In some cases these problems, although they turned out to be very serious, did not become evident until decades after the sites were planted.

Knowing the origin of seed is crucial to determining where it will survive and grow successfully. By the early 1960s a system was established in Washington that made it possible to certify that seed had been obtained from a particular stand. The system was used by the Northwest Forest Tree Seed Certification Association and administered by the Crop Improvement Association, Washington State University Extension Service. In 1966, a statewide seed zone map was developed by local groups knowledgeable in topography, weather, climate, and tree growth. This map was based primarily upon knowledge of Douglas-fir, but was intended for use with all tree species. The map was revised in July 1973. *(See historic seed zone map on next page.)*

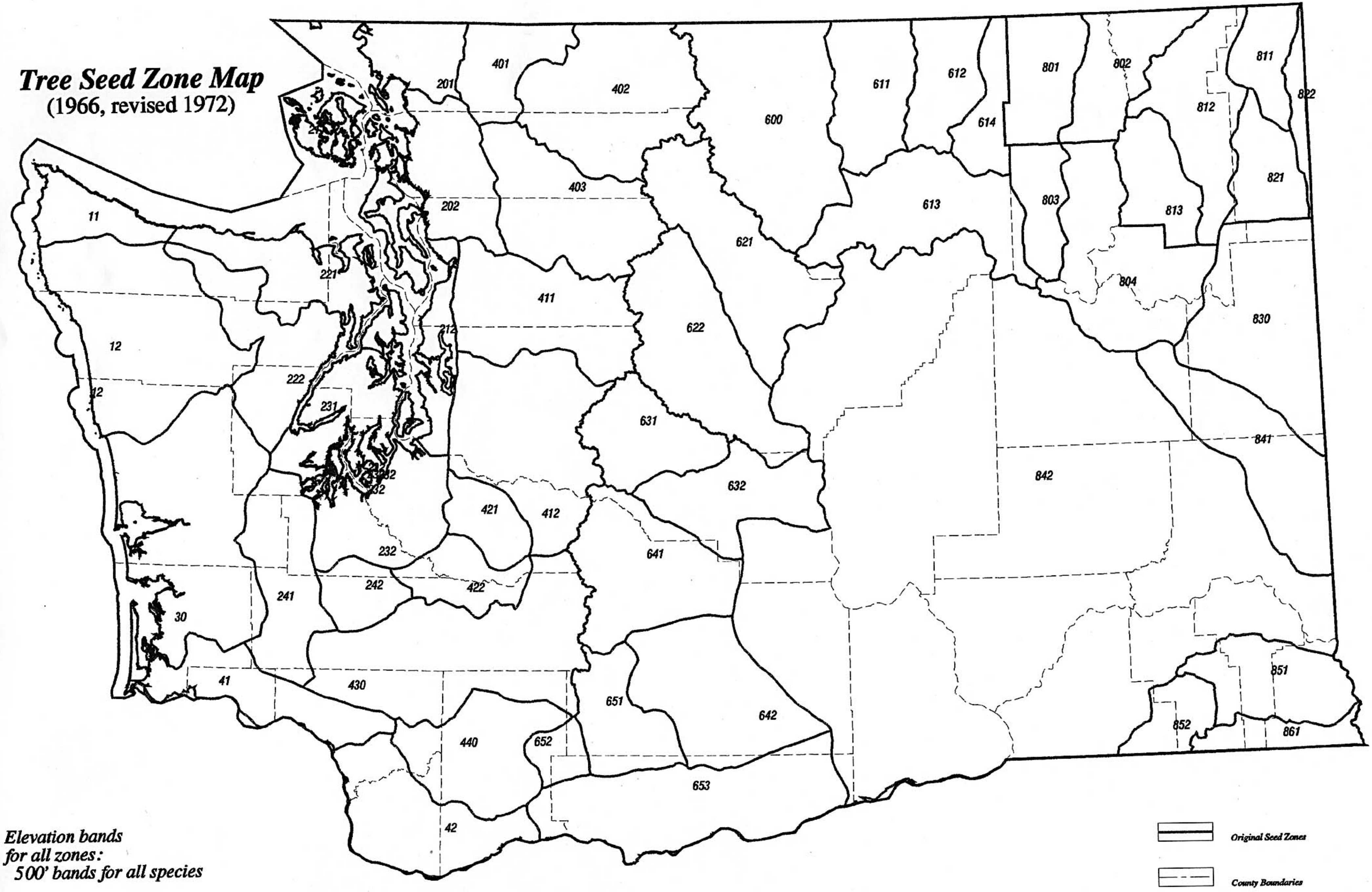
The differences we see among trees are determined in part by genetic differences and in part by environmental influences. Native conifers of the Pacific Northwest have the highest levels of genetic variation found in plants (Hamrick *et. al.* 1992). Forest tree species in this region exhibit large genetic differences in survival, growth rate, frost hardiness and other important traits. Some of these genetic differences exist among populations and some of them exist among individuals within populations. In most cases, genetic differences among populations of a species are the result of adaptation to different environments. For several decades, genetic differences among populations have been recognized as an important consideration when selecting appropriate sources of seed for artificial regeneration programs. The use of seed zones is based on the assumption that the local population, which is the result of thousands of years of natural selection, is best adapted to the site.

The range of each species includes an array of environmental conditions. Within that range there are distinctive habitats for which certain trees within that species are better suited. Tree seed zones divide the range of a species up into areas where the habitats are fairly similar. The size and shape of these zones varies depending upon the environment, the species, and its pattern of genetic variation.

The size of a tree seed zone can range from just a few thousand acres in the mountains of the western United States to many thousands of square miles in the gentle topography of the southeastern United States. This is because the environment varies significantly over short distances in mountainous terrain, but only over long distances in some flatter areas.

The size of tree seed zones is also affected by differences among species. For example, Rehfeldt (1993) found that differences in the length of the frost-free period were especially important in determining how genetic differences would develop among populations and how far their seed could be moved. For Douglas-fir, a difference of more than 18 days in the length of the mean frost-free period between populations meant they were genetically different and seed should not be exchanged. For ponderosa pine, the interval required to delineate population differences was 38 days, while it was 54 days for western redcedar, and more than 90 days for western white pine.

Tree Seed Zone Map
(1966, revised 1972)



Elevation bands for all zones: 500' bands for all species

Developing Seed Zones

The most reliable seed transfer guidelines would be developed after finishing long-term field tests of trees grown from seed collected in many populations from across a geographic region and planted across a range of environmental conditions. However, determining whether trees are adapted to a site takes a long time, sometimes more than 50 years (Roy Silen, personal communication, March 1995). Another valuable approach, when results from long-term tests are not available, is to map genetic patterns of geographic variation with a seedling study. The theory behind this method is that the larger the genetic difference between two populations, the larger the adaptive difference between them, and the greater the risk of moving seed between them. The assumptions behind this technique are that genetic differences between populations are largely adaptive, that the local population is most suited for a particular site, and that a map of genetic variation is also a map of the environment that shaped natural selection. Adaptation to environmental conditions is apparent when genetic and environmental variation are closely correlated; for example, when higher elevation sources set bud earlier. These tests can also identify the fastest growing families; long term tests of Douglas-fir in western Oregon have shown that trees tend to grow at a steady rate and that the fastest growing families can often be determined at an early age. However, this technique must be applied cautiously. A source or family that grows rapidly for a short period of time may not survive for the long term.

Both long-term field tests and seedling studies start by choosing many parent trees from across the area of interest, collecting seed from them, and growing the seedlings in the nursery. For long-term tests, nursery seedlings are then planted at several locations where the site conditions reflect the range of environments for that species in the area under study. Seed transfer recommendations are made after assessing survival, growth, and tree development for many years. The seedling- study approach utilizes the seedlings which are grown in more than one environment while they are still at the nursery. A large number of traits that relate primarily to growth and phenology are measured to determine patterns of genetic variation. Geographic areas or distances within which seed can be transferred without undue risk of maladaptation are estimated from observed genetic patterns. However, one must remember that seedling tests do not evaluate all risks. Seed transfer zones developed from them should be considered provisional until long-term field results become available.

Genetic differences among populations usually develop in response to variation in important environmental factors, especially temperature, length of the growing season, and moisture. A continuous change in these parameters from one location to another is known as an environmental gradient and a continuous genetic change along this gradient is known as a cline. Ideally, seed zones would be determined by knowing how these important environmental factors change across the landscape and how the species adapt to these changes. However, little is known about temperature and moisture in most forested parts of the West. This is because most climatic information is gathered for agricultural use from weather stations in the lowlands. Few weather stations exist in mountainous forested regions. Therefore, genetic researchers in the western United States have based tree seed zones and seed transfer rules on surrogates for climatic data that are easier to measure. Some of the most commonly used variables are elevation, latitude, longitude, distance from the coast, and distance from the crest of major mountain ranges. Because the zones that are developed from these analyses are based on the relationship between genetic variation and geographic factors rather than climatic factors, they may not be appropriate if there are large changes in climate. Other surrogates for climate which have been tested, but have usually turned out to be less useful, are slope, aspect, habitat type and soil type.

Since geographic variation and genetic variation are usually continuous variables, mathematical models that describe the relationships between them can be developed. These models usually provide the best estimate of risk when transferring seed. The larger the predicted genetic difference between populations from the seed source and populations from the planting location, the greater the risk of seed transfer. These models generally use the distance of the transfer, for example, in degrees latitude or longitude and feet of elevation, to estimate the risk of maladaptation. Unfortunately, many of these models are quite complex and people are often reluctant to use them. In addition, the research needed to develop these models has not been published for most of Washington. For these reasons, the recommendations that follow are based on seed zones instead of mathematical models.

Mathematical models have been developed for parts of Idaho and Montana for some species. In some cases, these models may apply to the northeast corner of Washington. These models are available on an electronic web page maintained by the Idaho Panhandle National Forests at their Coeur d'Alene nursery (Mary Mahalovich, personal communication, August 2000). Landowners in the northeast corner of the State may want to consider this source of additional information.

In Washington, there has been very little research specifically designed to determine the limits of seed movement. However, this work has been done in areas that surround Washington, including Oregon, Idaho, and British Columbia. Generalizations derived from studies in these nearby areas can often be applied in Washington. Indications of how far seed can be moved may be obtained from other types of studies as well; for example, ones that are designed to identify the fastest growing trees. Some excellent information can also be obtained from studies of seed collected in Washington and tested in Europe. Some genetic studies are now in progress in Washington and additional ones are planned. As the results of these studies become available, the recommendations in this document may need to be modified.

The areas included in the seed transfer zones in this document are based on the maps of species distributions developed by Elbert Little (1971). In some cases, Little's maps do not reflect current knowledge of the species distribution. In these cases, the seed transfer zone maps have been modified as suggested by local experts.

Since the environmental gradients and genetic clines are continuous, in many cases the borders between seed zones are somewhat arbitrary. If land ownership is split by a seed zone boundary, boundary adjustments may be possible to facilitate land management. This is especially true if a tree seed zone of a given size is moved north or south.

General Seed Transfer Guidelines for Washington

1. These guidelines only apply when planting on sites where the species naturally occurs within the seed zones.

2. Seed mixes should include seed from a number of different random locations within the tree seed zone and elevation band. If seed mixes are comprised of collections made only at one edge of a zone or only at one limit of an elevation band, a safe transfer might be about half a band width (either geographic distance or elevation) . Usually, this restriction would be more important for elevational and longitudinal transfers than for latitudinal transfers (Frank Sorensen, personal communication, March 1995).

3. Seed transfer to a higher elevation usually increases the risk of maladaptation; in other words, the potential for climatic damage. A transfer to a lower elevation will probably decrease productivity and may increase the risk associated with pest damage. If wood production is important and geographically localized collections are made, seed should probably not be transferred down to another elevation band.

4. Except for areas right along the coast, elevation does not have as great an influence as longitude for species on the west side of the Cascades. Latitude has less influence on seed transfer than longitude (Campbell and Sugano 1993, Campbell 1986, Sorensen 1983, and Campbell 1992).

5. Local populations are generally well adapted to local environments and are the safest to use until the best adapted, or better growing sources can be identified with data from long-term provenance tests (Namkoong 1969). This is particularly true for areas where large changes in the environment can occur over short distances, such as the islands in Puget Sound.

6. A seedling's response to its planting environment is significantly influenced by its parents' location (Campbell 1992).

7. Seed transfer zones should generally be smaller at high elevation than at low elevation (Campbell and Sorensen 1978). The size of seed transfer zones should decrease as site severity increases (Adams and Campbell 1982, Sorensen 1979). Therefore, less seed movement is possible at higher elevation Cascades sites. The steeper the genetic gradient and the harsher the planting site involved, the greater the risk of seed transfer (Adams and Campbell 1982). High elevations and harsh climates dictate that seed must be planted fairly close to its origin. However, close to the ocean at low elevation, seed movement becomes much less restrictive. The coastal climate permits most seed sources to survive, but those from harsher environments will grow much less than those from favorable environments which are better able to utilize the site potential.

8. When planting a species near its biological limits, a higher planting density is recommended and early thinning should be delayed to compensate for higher than normal mortality due to fewer seedlings being genetically adapted (Campbell 1975 and 1987). Shorter rotations would also reduce risk.

9. Risk of maladaptation is greatly increased when transferring seed across more than one environmental condition, for example, when transfer is from west to east and also from lower to higher elevation (Adams and Campbell 1982).

10. At both the geographic and elevational limits of a species distribution, natural regeneration should be strongly encouraged (Frank Sorensen, personal communication, March 1995).

11. If ownership or management would benefit by floating the zone boundaries north or south, that usually can be done. Sorensen (1994) stresses that seed zone boundaries do not represent abrupt breaks between populations that have large genetic differences. Instead, zone shapes are chosen to minimize the risk of transfer within their boundaries. The same applies for elevation (*i.e*. a 1000-foot band can be between 1700 and 2700 feet as well as between 2000 and 3000 feet if the former fits the species distribution or land ownership better) with the exception that the bands at higher elevation are often narrower.

12. Local conditions can also affect vigor. If wood production is important and there is a known area within a tree seed zone where growth rates are unusually slow, seed from that area should not be planted on more productive sites even if they are within the same zone and elevation. For example, throughout western Oregon there are many local areas on the east side of high ridges that receive less precipitation than the general area (i.e. they are in a rain shadow). Tree growth in these areas will be less than the growth in the surrounding area and transferring seed from these areas to those with more precipitation may result in reduced growth. This may also be true for the San Juan Islands and the islands in Puget Sound where changes in climate can be abrupt.

13. Relative humidity may be important; for example, transferring seed from a warm, dry area to a cool, moist area may increase the incidence of foliar disease (Nelsen *et al*. 1989).

14. Seed orchard seed is most safely used in the breeding zone of the parents or in the area where the parents have been tested (Campbell 1992).

15. The recommended number of seed parents in a seed lot ranges from 15 to 30. If there is equal representation from each seed parent, then the smaller number is suitable; if there is unequal representation, then the larger number is appropriate (Adams *et al.* 1992). Regardless of the number, the parents should represent a seed zone-wide mix. When specific information about the origin of the seed is maintained, single stand collections are acceptable. This gives the forester the flexibility of combining seed from multiple stands to create a seed zone-wide mix or using mathematical models to determine how far the seed from a single stand can be moved.

16. Small populations of a species separated from the main part of the range may be genetically unusual. If possible, the genetic composition of these populations should be protected by replanting them with seed collected from the isolated population. These populations can also be regenerated naturally. If these options are not practical, seed should be obtained from nearby portions of the main part of the range.

17. Seedlots should be labeled with the most specific information available on collection location and elevation. This will give foresters the most flexibility in using the seed.

Seed Orchard Seed

In some cases, the restrictions on seed movement that are recommended in this document may not apply to seed orchard seed. Many seed orchards are supported by a series of field tests. These tests evaluate the ability of trees in the seed orchard to produce offspring with good growth and survival for a certain planting area. In some cases, the trees in these seed orchards may have been selected to produce offspring that perform well over a large area. In these cases, it may be possible to expand the deployment of this seed beyond what we recommend.

Prior to purchasing and using orchard seed, the purchaser may want to ask the following questions and compare the answers to the guidelines for general seed transfer:

1) What is the origin (*i.e.* geographic location and elevation) of the parent trees in the orchard in relation to the location and elevation of the intended planting site?

2) Are there genetic tests of the seed-producing parents or field tests demonstrating the performance and adaptability of the orchard seed?

3) What geographic area do the tests encompass? How do the test sites relate to the location of the planting site? For how many years have the trees been tested?

4) What are the results of those tests? How much better or worse than average were the seed parents based on the test results?

5) How many seed parents are represented in the seed/planting mix?

6) What is the risk of pollen contamination in the seed orchard? Pollen drifting into the orchard blocks from outside stands or geographically different orchard blocks may reduce gain or increase the risk of maladaptation.

7) What percentage of the trees in the orchard produce seed and pollen? Better adaptation is obtained when there are a number of parents, both male and female, represented in the seed lot.